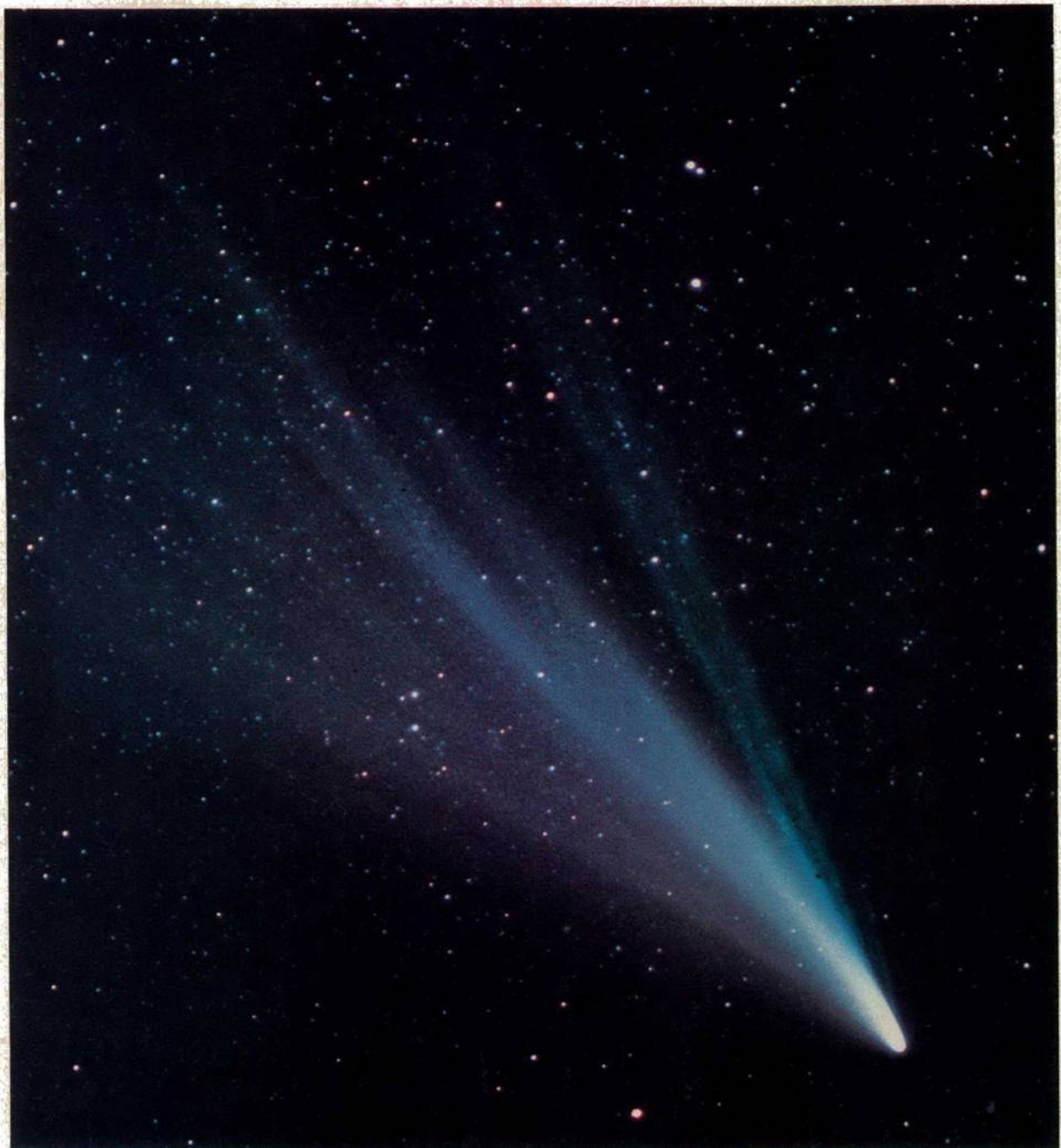


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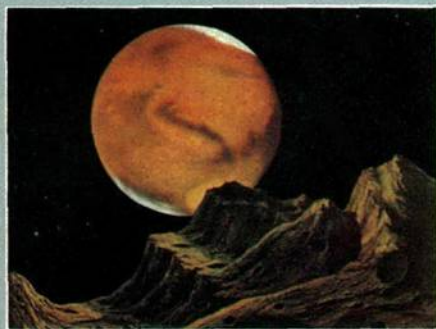
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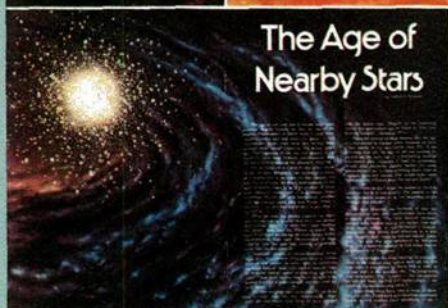
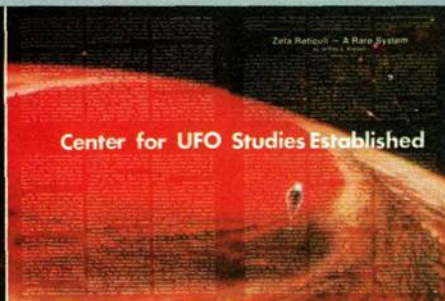
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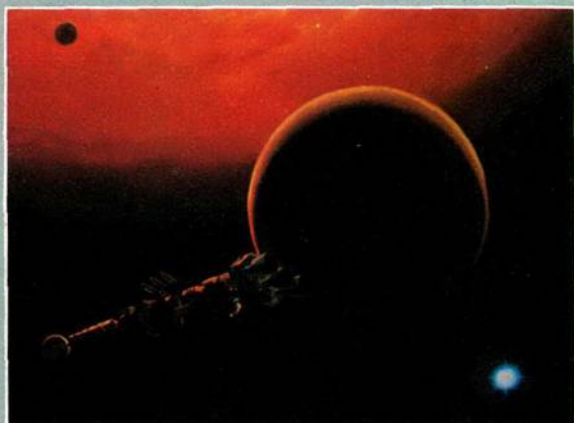
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ASTRONOMY

The World's Most Beautiful Astronomy Magazine

May 1976

Vol. 4, No. 5

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Cover

On March 7 of this year, comet West posed in the predawn sky for thousands of observers and astrophotographers. This photograph was taken by Bill Gordon from the Mojave Desert, 100 miles northeast of Los Angeles. The 10 minute piggyback exposure was obtained with a 135mm Bushnell telephoto lens at f/2.8; the film used was Fujichrome R-100. ASTRONOMY's comet West pictorial begins on page 18.

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QUASARS: ODDITIES OF SPACE

by
Jeanne Hopkins



sternbach



Obscured by thick lanes of dust and not directly visible, a quasar erupts in the Milky Way's center, lighting up the sky. This scene, viewed from a planet at the same distance from the galactic core as Earth, could only have taken place several billion years ago, probably before Earth formed — if it happened at all. A recent theory suggests that violent activity at our galaxy's core may be due to a massive black hole — a "dead" quasar. Artwork by Rick Sternbach.



During the 15 years since quasars were discovered, scientists have reached no general agreement on where quasars obtain their prodigious supplies of energy, how distant they are, or even what they are. Like the flight of the bumblebee, long considered aerodynamically "impossible", the existence of quasars violates the known laws of physics: No object as small as a quasar should blaze so brilliantly for so long. Yet quasars shine in spite of their impossibility.

Scientists have been struggling over the nature of quasars since the objects were discovered in the early 1960s. Radio astronomers had detected several radio sources that apparently covered unusually small areas in the sky — too small for the sources to be nearby gas clouds (the only radio sources then known), yet much too strong to be very distant. These peculiarities intrigued optical astronomers. But radio telescopes didn't possess sufficient resolving power to pinpoint the sources, so optical astronomers were left without any spot to zero in on.

By a happy coincidence, one of the strongest radio sources, 3C 273, was occulted by the moon in 1962. Three Australian radio astronomers (directed by Cyril Hazard) took advantage of the occultation to establish 3C 273's coordinates with unprecedented accuracy. They found the radio source had two components separated by 20 seconds of arc. Star charts failed to show any visible object at the position of the stronger radio component, but the coordinates of the weaker component coincided with the position of a 13th magnitude blue "star". This object appeared in all photographs that had been taken of that region in the constellation Virgo, but it had been regarded as an ordinary star of no particular interest, unworthy of study.

Hazard and his colleagues provided Maarten Schmidt with their information; Schmidt then turned the 200 inch Hale telescope onto this star. Even at that resolution, the object remained a blue point of light. But next to it, at the exact position of the radio source's stronger component, there was a faint bluish jet. Stars do not show jets, so this object was obviously not a star. It represented a new celestial species.

Other members of this peculiar new class, along with 3C 273, were dubbed *quasi-stellar radio sources*, soon shortened to *quasars*. The word quasar is now a misnomer, since more than half of the known quasars are not detectable at radio wavelengths. Quasar hunters located their prey by comparing two photographs of the same region of the sky taken through

different colored filters. Any objects that seemed to be unusually bright at the blue-violet end of the spectrum were targeted for further study. The method had its disadvantages, and with the improved resolution of radio telescopes, astronomers went back to locating quasars with the help of radio observations.

Schmidt obtained a puzzling spectrum of 3C 273. It was not a continuous spectrum with dark absorption lines like that of a normal star, but had bright, broad emission lines like those of a gas cloud. What made no sense was that the positions of those emission lines did not correspond to spectral lines of any known substance.

In February 1963, Schmidt suddenly realized that 3C 273's spectral lines corresponded to the lines of hydrogen, but greatly displaced or redshifted from their normal positions.

Light waves from a moving source are affected in the same way that sound waves are. Light from an approaching source is compressed, or shifted, toward the high frequency, blue end of the spectrum, while that from a receding source is displaced toward the red, low frequency end. Known as the Doppler shift, the effect is a valuable astronomical tool used to determine the line-of-sight velocities and rotational speeds of stars. Almost all familiar objects have velocities of a few hundred miles per second at most. But quasars exhibit redshifts that, if they are Doppler shifts, correspond to speeds 15 to 90 percent that of light.

Where do quasars get such enormous speeds? The simplest answer, proposed from Hubble's law, is that the speeds are a result of the universe's expansion. Half a century ago Edwin Hubble discovered that all distant galaxies are receding — fleeing from us as if we were, in the words of Sir Arthur Eddington, "the plague spot of the universe". The farther away a galaxy is, Hubble said, the faster it is moving away. If this recession speed is due to the overall expansion of the universe, then quasars lie at the "edge" of the universe.

To be so bright so far away, quasars must have the intrinsic luminosity of 1,000 Milky Way galaxies. In addition, the rate at which their light output varies limits their size to only about a light-day across, about twice the diameter of Pluto's orbit around the sun. It's hard to conceive of a group of objects with the luminosity of 1,000 galaxies packed into a volume the size of the solar system.

Myriad explanations are offered to substantiate what quasars are and why they appear to act as they do, and some of the explanations are rather far-out. One of the more radical of those suggested models is the "gravitational lens". Essentially what science fiction writers would call a space-time warp, it is related to Einstein's view that light is affected by gravity. Matter, the theory says, curves space-time so that a light ray travels along a curved path instead of a straight line. The greater amount of mat-

A quasar bursts from the nucleus of a galaxy in this rendering of a hypothetical quasar origin. Recent information closely ties quasars to galactic core explosions, and one current theory suggests that quasars may be ejected from a galaxy's center in the same way that great clouds of material are seen shooting from a quasar in some photos. This explanation would make the objects smaller and nearer than their observed redshifts indicate. Artwork by Adolf Schaller.

ter present, the more the light's path is curved. At large distances, this intrinsic curvature of space-time creates a "lens" of great focal length, magnifying faraway objects so they appear brighter than they really are. Because of this effect, the apparent size of an object eight billion lightyears or more away actually *increases* with distance.

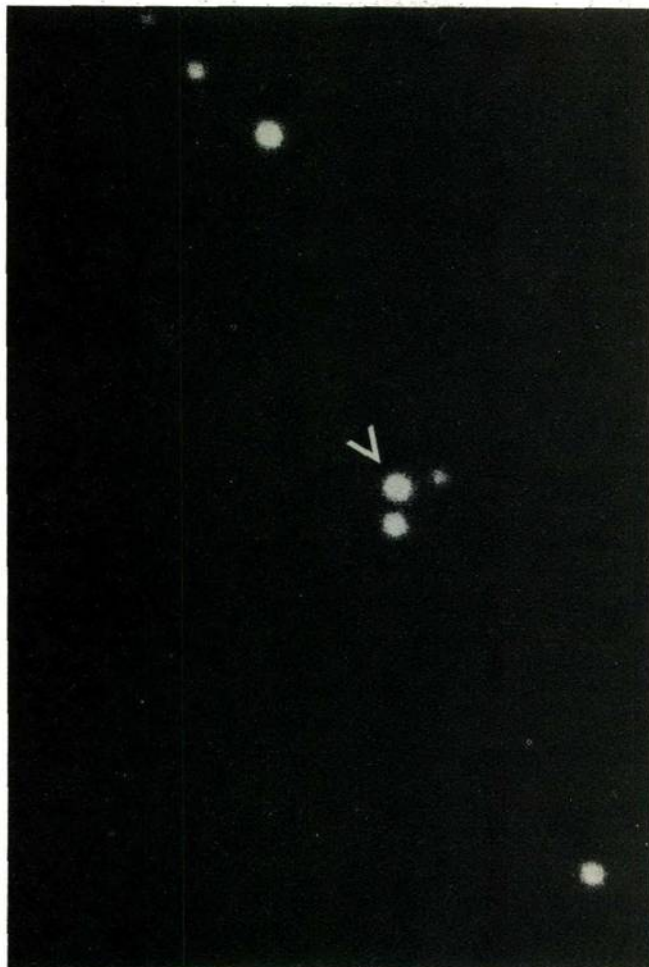
Another ingenious model has been proposed by Israeli physicist Yuval Ne'eman. He suggests that quasars are "lagging cores" — parts of the primordial black hole temporarily left behind after the big bang. According to his model, the light we receive from quasars comes from their "little bangs" as they explode into our universe.

Ne'eman's model raises questions on the variability of time. In the first few moments after the big bang, time in the exploding regions would have passed very slowly, while time in any regions that lagged behind would have gone by quickly. A sufficient amount of time could have passed for galaxies to form and evolve in the lagging regions while the temperature of the expanding regions was still too high for matter to exist. If quasars originate in these lagging regions, then when we "see" quasars we may be looking not into the remote past but into the remote future.

If the universe is as lopsided as the lagging core hypothesis implies, astronomers should be able to detect this lopsidedness. The fact that they cannot, seriously damages the theory — the universe seems to be expanding uniformly in all directions.

Critics of this cosmological view of quasars suggest that the observed redshifts indicate a speed of recession that is not caused by the overall expansion of the universe. Quasars could be objects shot from the core of our galaxy sometime in the last few million years. If their initial speeds were high enough, they would all have passed us and would display the observed redshifts. This interpretation of a Doppler shift — placing quasars within a few million, rather than the generally accepted several billion light-years of us — would reduce their energy requirements to the luminosity of a "mere" three or four galaxies. Quasars can't be nearer than several million light-years because none of them have detectable proper motion. If they were in the Local Group of galaxies, they would have produced observable gravitational effects on nearby galaxies.

The recent discovery that the nuclei of virtually all galaxies, including the Milky Way, are sites of violent events supports this view. A chain of supernovae is one of the few things known that would provide the exorbitant amounts of energy needed for quasars to "shine". In galactic nuclei (densely packed conglomerations of old stars), one supernova could eject its debris into the path of a nearby star nearing the end of its life, accelerating the second star's evolution. The accompanying shock waves could throw that star out of its orbit, to col-



lide with another star. Such disruptions could cause a chain reaction of supernovae in a galactic nucleus, forcing the ejection of quasars.

Evidence is piling up that quasars are closely connected to galactic core explosions. Cambridge University astronomer Donald Lynden-Bell has suggested that the violent activity recently detected in the Milky Way's core may be due to the presence of a massive black hole in the form of a "dead" quasar. Other astronomers suggest that the peculiar object BL Lacerta may be a quasar embedded in the nucleus of an otherwise normal galaxy (see "Stranger than Quasars", *ASTRONOMY*, January 1976).

If quasars are objects shot out of galactic nuclei, why haven't some been hurtled in our direction? One flung toward us would show a blueshift; but, not one of the hundreds of quasars known display such a shift. If they had been ejected in the far-distant past or at high speeds, all the nearby quasars would have passed us, while the general expansion of the universe would have carried the more distant ones beyond us. This possibility leaves the door ajar for the "ejection" hypothesis.

Physics admits only two methods that produce a redshift. One is the Doppler shift mechanism. The other, submitted by Einstein, showed that light emitted by a massive, dense body would have to make its way up against the gravitational pull of



Most photographs of quasars resemble this one of 3C-147 (opposite page). The quasar is visually indistinguishable from nearby stars. The finest photograph yet obtained of a quasar is that of 3C-273 (above), the first quasar to be so recognized. The gas jet bursting from the object's center is a strong source of radio waves. These pictures emphasize the difficulty in identifying quasars' true nature. Hale Observatories photographs.

that body. Some of the light beam's energy, spent overcoming the body's gravity, would effect a redshift of the beam's spectrum.

To attribute the redshifts of quasars to an Einstein effect, single, ultradense objects less than 500 light-years away whose combined masses would exceed the total mass of the Milky Way would be necessary. If the sources were extragalactic, their combined mass would have to exceed the mass of the universe. Such objects, if they exist, surely would not go undetected. They would use up their energy so fast that astronomers would have noticed changes in luminosity even in the short time quasars have been studied — although quasars' images that appear on star field photographs taken decades ago seem so different from those of the same quasars taken today. Furthermore, light emitted from the outer regions of such an object, where the surface gravity was weaker, should present a smaller redshift — contrary to observations. Evidence suggests, in addition, that a quasar's light comes not from a central source but from sources scattered throughout the quasar.

Unless there is a third, as yet unknown method — and astronomers no longer scoff at the idea — then the redshifts of quasars must be produced by one of these methods, or a combination of them. Both present difficulties.

The foundation of present-day cosmology is Hubble's law, whose validity has been verified repeatedly by the redshifts of galaxies. All quasars associated with strong radio sources apparently obey Hubble's law, although the radio-quiet quasars show no correlation between apparent brightness and redshift. Are there several different kinds of quasars? Are some quasars' redshifts cosmological while others are "local" or gravitational? Do others, displaying spurious redshifts, bear no relation to any known physical process?

The whole problem of quasars is that they are too small to generate as much light as they do and maintain that light output over such a long period of time. It is unlikely that the true nature of quasars will be discovered for years, but physics has already been enriched by the theories advanced to explain them. 

*Jeanne Hopkins has been the chief manuscript editor of the **Astrophysical Journal** since 1967. Her book, **A Glossary of Astronomy and Astrophysics**, is scheduled for publication this spring by the University of Chicago Press.*



sternbach

The background of the entire page is a vibrant cosmic scene. On the left side, there is a large, bright, orange-red nebula or explosion, with numerous smaller, distant stars and galaxies scattered across the dark blue and black space. The overall effect is one of immense scale and energy.

COSMIC EXPLOSIONS

by Gerrit L. Verschuur

The entire core of a galaxy releases an incredible quantity of energy and matter in one titanic explosion. Millions of stars may be exploding simultaneously in a chain reaction, or a gigantic implosion (such as a massive black hole) may be causing other events leading to the energy outburst. An exploding galaxy can release more energy than the total output produced by all its stars. The brightness of some explosive cores can vary from week to week. Artwork by Rick Sternbach.



When we examine the overall universe, instead of inspecting individual objects, we find that it can be an incredibly hostile place. Violent phenomena occur within and on the surfaces of stars, in galaxies and quasars. The vehemence of some of these explosive events may lead us to wonder how we have survived for as long as we have.

Whether in the sudden tiny explosions that occur when pea sized meteors slam into the moon, or the gigantic explosions that take place in the nuclei of some galaxies, the same basic phenomenon occurs: A large amount of energy is quickly released in a small volume of space. The matter in that volume is rapidly heated and converted to a high temperature, high-pressure gas that expands violently, producing an explosion. Astrophysicists who search for the mechanisms that cause explosions must account for each link in the chain. Where does the energy come from? Why is it released suddenly rather than slowly? How can it be released in a small enough space to cause violent heating and expulsion of material? In what manner does the exploded material actually move out from the explosion? The validity of astrophysicists' theories is determined by their ability to account for these, and other more detailed, questions.

Some explosions can be easily accounted for — for example, those that take place during crater formation. If a tiny meteoroid enters Earth's atmosphere at about 50 miles per second, it quickly heats by friction; its outer layers become red hot, surrounded by a layer of superheated atmosphere. Half a second later, and 50 miles down, the last bits of the meteoroid vaporize, and the event ends without an explosion. The frictional release of the meteor's kinetic energy was much too slow and spread out along miles of the meteor's path. But if an identical meteor hits the moon at 50 miles per second, it blasts a crater many times the size of the meteor. A meteor that hits lunar soil slows and releases its energy in a fraction of a millionth of a second, and this energy is contained in a small volume: the meteor and the bit of rock it strikes. This small rocky mass, heated to an incandescent gas, will expand and push other rock before it — and, with a rush of rock and gas, a new lunar crater is formed. Because the release of energy was so sudden and so rapid, the event is an explosion.

Much larger events take place on the surface of the sun, which is constantly being churned up on scales ranging from granulations 1,000 miles across to sunspots with areas of tens of thousands of miles. Sometimes sunspots appear in groups with mag-

netic fields that emerge from one sunspot and disappear into another. Around spot groups, the field lines become scrambled, and magnetic fields aimed in opposite directions will annihilate one another. Magnetic energy is converted into some other form of energy — in this case, violent motions of the atoms in the vicinity — and manifests itself as an explosion. We see the result as a flare (a brightening of a small area of the sun's disk for a brief period of time). Flares blast clouds of particles from the sun's surface through its corona (where the particles trigger radio signals). These clouds continue out into interplanetary space and may even reach Earth. The magnetic field of Earth protects us from the particles, which otherwise could produce damaging effects in our atmosphere. Trapped high above us by this magnetic field, the solar particles form the Van Allen belts that surround Earth.

We can think of the sun as a continuous, giant nuclear "fire". Deep inside the sun, the conversion of hydrogen into helium releases large amounts of energy. No explosion occurs because the energy release is steady and occurs in a large volume inside the star. The outer, cooler layers of the star keep it from exploding by their sheer weight, and the energy generated in the core leaks out in a controlled way, without tearing the sun apart. If the outer layers of the star were suddenly removed, the remains of the star would quickly erupt. Our sun can be thought of as a fusion reactor, the control being provided by the thick layers of hydrogen not taking an active part in the fusion process.

We know of other stars that have flares as bright as the stars themselves. Light flashes, followed hours later by radio emissions, indicate that large parts of the surfaces of those stars must have brightened very suddenly, ejecting material as they did so. Perhaps the mechanism responsible is like a giant solar flare; perhaps the stars are binary — their flares caused by matter from a companion star falling onto the surface of the flare star. Whatever theory is finally accepted will have to fit data from a large number of observations.

Stellar explosions can be even more violent. At the ends of their lives, some stars enter the planetary nebula phase, during which they shed an outer shell of matter. While not a very violent phenomenon in comparison with some other stellar explosions, this ejection of the outer layers of the star nevertheless involves huge amounts of energy. The star is slowly "going out" for lack of fuel when the planetary nebula phase starts. Its cooling outer layers start to absorb more energy than they had when they were hotter, heating up and then being "blown" outward in a mild sort of explosion.

Sometimes stars explode totally. People have witnessed these great events in the past without the aid of telescopes, even when they occurred as far away as 18,000 light-years. A star exploding so violently appears as a "new" star, where none

A giant flare erupts from the surface of the sun, spewing matter more than 360,000 miles into space, in this photograph taken Dec. 19, 1973 from Skylab 4. Only a few hours earlier, the flare had been nothing more than a rather large prominence — indicating the extreme speed with which explosive events occur. This photo was taken in the light of ionized helium by an extreme ultraviolet spectroheliograph instrument. NASA photograph.

had been visible before. These exploding stars are called supernovae. By chance, none have been seen in our galaxy since the invention of the telescope, and scientists have been unable to study one carefully. Many astronomers hoped that Nova Cygni 1975 would be a supernova, but after several days realized the new star was a smaller explosive event called a nova.

Nova Cygni 1975 suddenly brightened by a factor of 40 million times — not enough to qualify as a supernova, but an extremely bright nova. If a nearby star like Vega were to increase to such an extent, it would shine nearly 1,000 times brighter than the moon for a few days. Current theory states that a nova explosion is created when hydrogen from one member of a binary star system falls onto the very hot surface of its white dwarf companion. Nuclear fusion of hydrogen to helium follows, rapidly releasing energy into a small space. Heating and violent expansion — an explosion — follow.

The supernova event, on the other hand, occurs in the interior of a star much more massive than the sun, when the star reaches a point in its evolution where iron forms at the center. The iron has the tendency to consume more energy than it liberates when it undergoes nuclear fusion. This produces a cooling effect, and the core of the star cools so fast that it implodes under its own weight. The upper layers also come crashing down — their gravitational energy heating them and triggering still more energy release by nuclear fusion, forming great quantities of heavy elements. Most of the star's mass then explodes away from the incredibly crushed core. The brightness of the star can increase a billion times — so much so that we can see supernovae exploding

even in distant galaxies. In fact, the light emitted in such cataclysms can often outshine the entire galaxy for weeks.

Again, we might wonder what it would be like to see a relatively nearby supernova. The supernova of 1054 A.D. (which formed the Crab nebula) — even though located 6,000 light-years from Earth — could be seen for weeks, even during the day. At more distant times in the past, before recorded history, there may well have been closer supernovae. Early man may have looked up in fear at this new sight that must have lit the night like day. If Vega were to become a supernova, its brightness would approach that of the sun.

But stellar explosions, unimaginably large as they are, are small compared with the energy released in the nuclei of some galaxies. In our relatively peaceful Milky Way, we can hardly imagine what the explosion of an entire galaxy must be like. Even though we can see such events occurring throughout the universe, we have yet to understand what causes such titanic explosions. All we are certain of is that, at the centers of some galaxies, vast amounts of energy are released and material is expelled. We cannot say whether millions of stars are exploding simultaneously, or whether there is some catastrophic implosion similar to a black hole at the center, causing other events that lead to the energy emission. The quantity of energy being emitted by an exploding galaxy is enormous — often greater than all the energy coming from all its stars. If the process for energy generation is the conversion of hydrogen to helium (the same as that used in stars), then billions of stars must exist in a tiny volume of space and change their brightness in uni-

Energy of Explosive Events

Event	Ejection Speed of Material	Energy
Impact of dime from six feet	—	10^6 ergs
Impact of pea sized meteor at 30 km/sec	—	10^{13} ergs
Volcano	—	10^{25} ergs
Impact of 1-km asteroid at 30 km/sec	—	10^{29} ergs
Solar transient	200-1000 km/sec	10^{31} ergs
Solar flare	500-2000 km/sec	10^{32} ergs
Flare star	—	unknown
Novae	Up to 1000 km/sec	10^{44} ergs
Emission of sun over 10,000 years	—	10^{45} ergs
Planetary nebula	20-50 km/sec	10^{46} ergs
Supernova	Up to 10,000 km/sec	10^{49} ergs
Milky Way center	100-200 km/sec	10^{54} ergs
Exploding radio galaxy	Unknown	10^{56} ergs
Quasar	Near light speed?	10^{58} ergs
Energetic radio galaxy	Unknown	10^{61} ergs
Big Bang	Light speed	10^{76} ergs

The unit of energy used in this table is the erg. The table is intended to give an idea only of the relative scale of explosive events. The size of one erg is difficult to visualize — a mosquito flying into a wall expends about one erg of energy.



This special photograph, taken in blue light, of the galaxy M-82 reveals that it is being wracked by a massive explosion. The filaments extending from the galaxy's center reach more than 25,000 light-years into space. The cause or trigger of such an explosion is unknown; one theory states that a supernova occurring in the closely packed central region could begin a chain reaction resulting in the kind of upheaval demonstrated here. Hale Observatories photograph.

son, since the brightness of some explosive cores of galaxies changes from week to week. We can hardly imagine so many stars crowded so close together in a space only a few light-years across.

We know that in some of these exploding galaxies, the energies released by the eruption are equivalent to a transformation directly into radiation of all the material in millions of stars. The well-known equation $E=mc^2$ states that matter has energy (or energy has mass) related by the speed of light squared. This equation tells us how much energy we can extract from a given amount of mass. Only if the mass of millions of stars is converted completely into energy can we possibly explain the galaxy explosions. No one has decided how such a conversion could be started, or even continues.

Evidence shows that our own galaxy may have suffered an explosion at its center sometime in the past. The energy of that explosion, however, was small in comparison with some of the other galaxies.

If exploding galaxies are hard to understand, then quasars — apparently located much farther beyond the galaxies and outshining them as a result of what must also be enormous explosions in their interiors — are even more difficult to explain. The essence of the quasar problem is that, in addition to being extremely far away, they are also quite

small, and the intense light and radio emissions are generated in tiny regions at their centers. It is possible that all galaxies go through a "quasar phase" at the beginnings of their lives. If this is indeed the case, quasars shine so brightly that it would be almost impossible to see the surrounding galaxy.

One thing is certain about the exploding galaxies and quasars: Incredibly violent events appear to be taking place within them. These must be explosions because they eject enormous clouds of matter into space. These clouds travel outward — in some cases, for distances of many millions of light-years — radiating strong signals as they go. We often find double radio sources, in which two emitting regions are roughly centered on an optically visible galaxy. Sometimes multiple explosions appear to have wracked the galaxy, sending more matter outward along the same path followed by the first ejected clouds.

Finally there is the greatest explosion of them all, the initial event — the big bang — that apparently started the universe expanding. Our best estimate shows it happened perhaps 18 billion years ago. The amount of energy is all but incomprehensible — billions of times greater than the most energetic quasars. However, it set matter moving outward into space, and we still see results today when we look out at distant galaxies receding from us in our expanding universe.

Meteors, flares, novae, exploding galaxies, quasars — all are violent phenomena, and yet all are part of the natural order of the cosmos, despite their vehemence and apparent randomness. The universe is by no means the quiet place it appears to be when we look up at a "peaceful" night sky. 🌌

COMET WEST

by
Henry J. Phillips

On Feb. 25, 1976, comet West reached perihelion, passing less than 20 million miles from the sun. As the comet swung into the second half of its orbit and began pulling away from the sun, its tail streaming out in front of it, thousands of observers on Earth began searching the skies for it with a mixture of anticipation and tension. Would comet West live up to expectations and become fairly bright? Or would it fizzle out, disrupted by its close passage of the sun, into just another dim disappointment?

As matters turned out, all fears were groundless, for comet West exceeded all early predictions of its magnitude and became one of the half dozen brightest comets of this century. In addition, comet West exhibited unusual postperihelion behavior: its nucleus split up into four visible sections — something which has not been observed in any comet since 1882. Truly, comet West turned out to be one of the most exciting astronomical events of this or any other year.

In the jubilation over the comet's impressive appearance, a certain amount of relief could be detected. Although original estimates stated comet West would be quite bright for a short time after perihelion, astronomers felt compelled to bend over backwards in an attempt to avoid the kind of overkill that has greeted the appearance of other comets which subsequently failed to live up to expectations. The most notorious case in this regard is, of course, that of comet Kohoutek in 1973. In fact, comet West was played down so successfully that astronomers were faced with a barrage of "why didn't you tell us it was coming?" questioning when the comet became bright.

There was little time for a massive build-up such as Kohoutek received, for the discovery of comet 1975n was not confirmed until about three

months before its perihelion date. In late October, Richard M. West of the European Southern Observatory in Geneva found the comet's trail on a 60 minute exposure made Sept. 24. Further investigation revealed that the comet had left similar trails on exposures made in early August. The comet, named after its discoverer, had a magnitude of only 16 in August and 15 in September — about normal for a comet on first identification.

At the end of November, the Smithsonian Astrophysical Observatory published an ephemeris on comet West that included the orbit calculated from precise positions reported by West, as well as its predicted brightness. These predictions indicated that the comet, while certainly bright near perihelion, would not necessarily be a spectacular object, as it would fade to less than fourth magnitude by mid-March. Comets that become even this bright, however, are rare enough to be notable, and the waiting began.

But then comet West began acting up. During December and January, the comet consistently ran one to two magnitudes brighter than expected. It was at this time that the first comparisons with Kohoutek were made, and warnings were immediately issued saying that the brightness trend might not hold up during comet West's perihelion passage. The comet continued to brighten rapidly, and it could be seen with the naked eye a few days before perihelion. On February 25, hours before its closest approach to the sun, comet West was observed through the refractors of Harvard Observatory in

Opposite: A 30 minute exposure on GAF 200 captured exquisite tail structure in this photograph taken on March 13. A six inch f/6 home built reflector was used with an SLR body. This date was the last chance to photograph comet West without interference from the moon. Photograph by Brad Wallis.





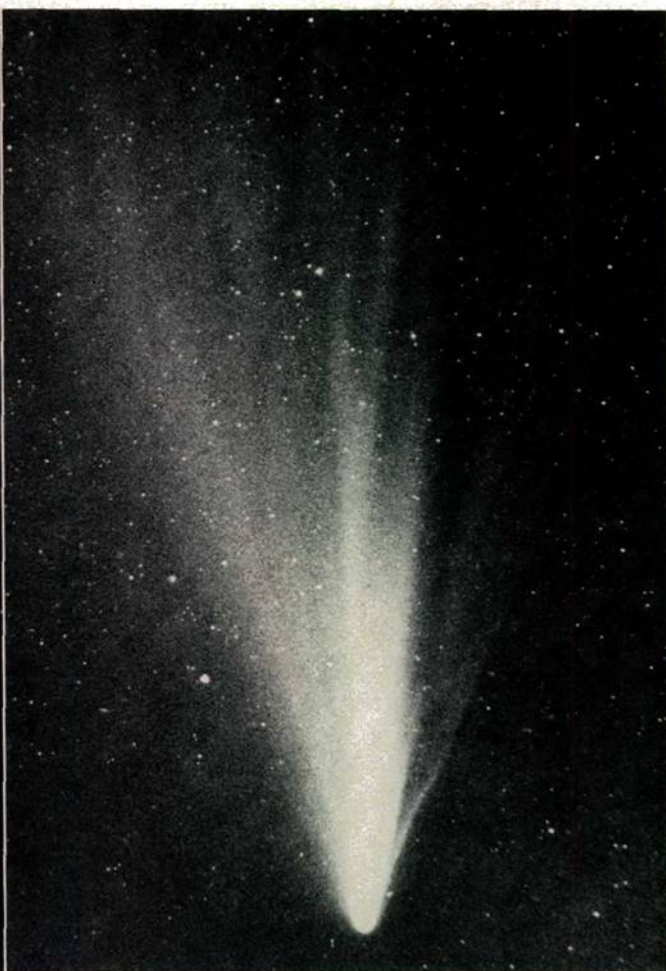
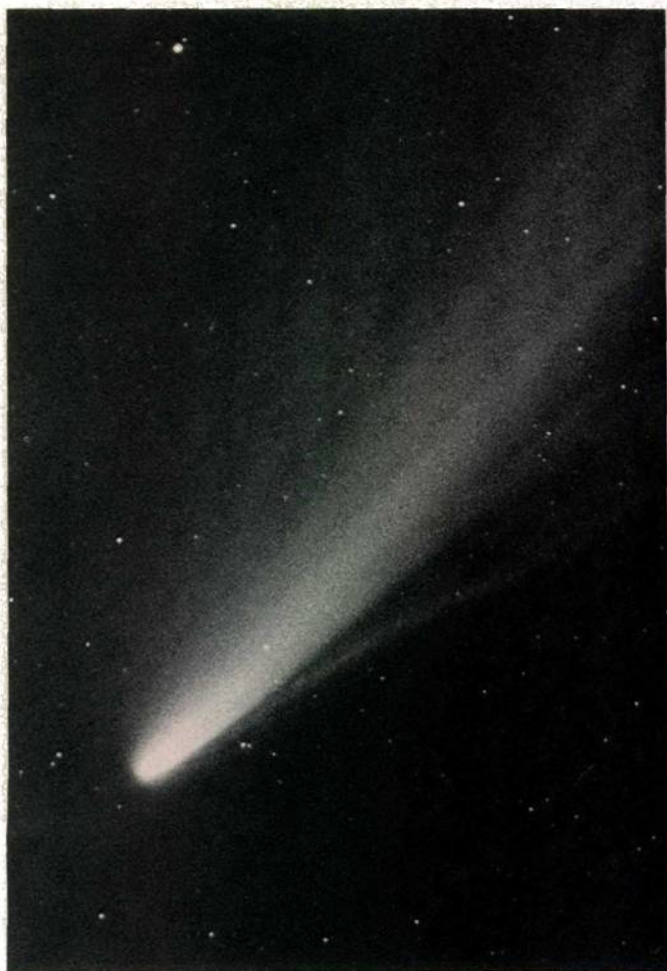


Opposite page, top left: Nearly lost in the twilight on the morning of March 1, comet West was recorded in a one second exposure with a 135mm f/3.5 lens on High Speed Ektachrome. The comet shines brightly through the twilight about a half hour before sunrise. Photograph by J. Westlake. Top center: On March 2, a 200mm telephoto lens captured the comet in a 12 second exposure on Fujichrome R-100. The tail extended some three or four degrees even in bright twilight, and the starlike nucleus may have been as bright as zero magnitude. Photograph by Pat Michaud. Top right: Wednesday, March 3, was the first morning comet West could be seen in all its splendor, well up in a fairly dark sky an hour before sunrise. The nucleus, reddened by the atmosphere, is clearly much brighter than nearby Enif (magnitude 2.3). The tail extends nearly 20 degrees in length, drifting gently to the north. This 20 second exposure on High Speed Ektachrome (pushed to ASA 400) was made with a 50mm f/1.4 lens. Photograph by Larry Koehn. Bottom: Visibility was excellent from Lumsden, Saskatchewan, and the comet stands out in the predawn sky in this photograph taken on March 4. To the naked eye, the tail swept much higher into the sky than shown in the 15 second exposure on Fujichrome R-100, taken with a 50mm f/1.8 lens. Photograph by Fr. Lucian Kemble.

Above left: From the Santa Monica Mountains in California, dawn had not yet swallowed up the comet on March 5, when this 10 second exposure on High Speed Ektachrome was taken with a 35mm SLR camera mounted on a tripod. The lens used was a 58mm f/1.4. Photograph by Stephen Reed. Above right: On March 6, this two minute exposure was made on Fujichrome R-100, showing the comet against a colorful dawn sky. The 50mm f/1.8 SLR was piggybacked to prevent star trailing. Photograph by George Briggs. Bottom right: A tripod mounted camera with a 50mm f/1.7 lens was used for a 30 second exposure on Focal 400 film. By March 7, as the photo shows, comet West could be seen in a completely dark sky. The blue plasma tail (right) is now clearly separated from the yellowish, bushy dust tail on the left. Photograph by Jodean Wachs.







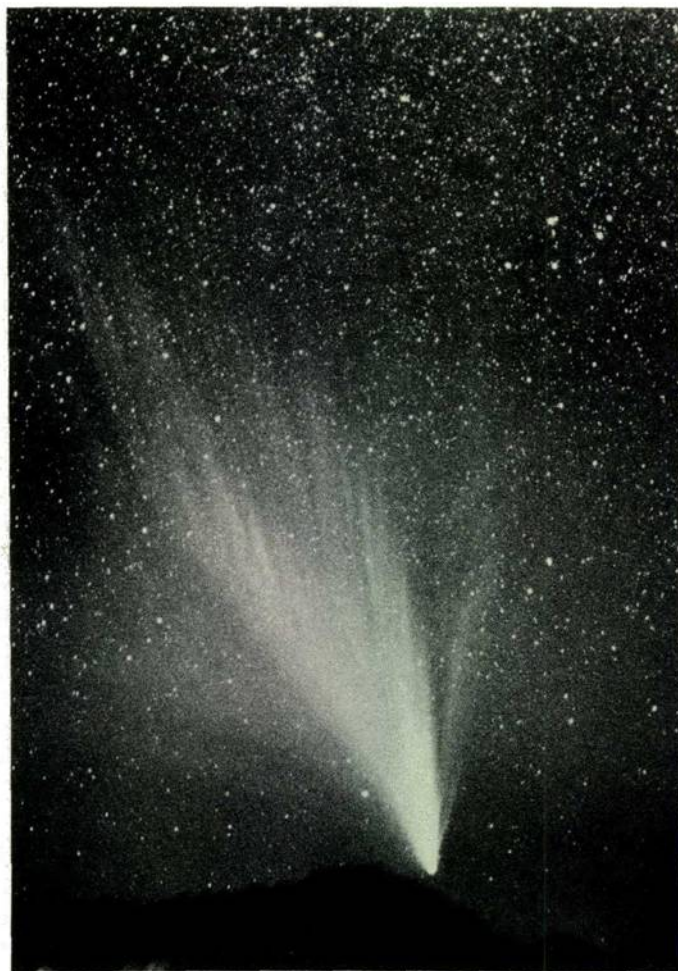
The early morning hours of Sunday, March 7, provided many observers with their first clear view of comet West. It rose well before sunrise, could be seen in a completely dark sky, and weather conditions over much of North America made viewing possible for the first time. Even residents of light polluted urban areas could easily observe comet West — one of the six or seven brightest comets of this century. Opposite page, top left: On the morning of March 7, comet West was an exciting sight. Short exposure photographs such as this one — a 20 second exposure on GAF 200, made with a 50mm lens at $f/1.4$ — show a close correspondence to the naked eye view. Photograph by Nicholas Guydosh. Top right: At a magnification of 100 times, comet West showed a bright starlike nucleus with a delicate, symmetrical coma and tail, and a central streamer extending straight from the nucleus. This photo is a two minute exposure on Fujichrome R-100, obtained using the Brooklyn College Weinrich Observatory seven inch refractor. From the murky skies of Brooklyn, only a 2-1/2 degree tail was visible to the naked eye. Photograph by Don Trombino. Bottom: From the clear skies of California, a 10 minute exposure on GAF 200 shows a broad dust tail stretching 20 degrees or more, crossed by many synchronic bands (thought to result from bursts of material being ejected from the nucleus simultaneously). A shorter, wispy plasma tail of ionized gases, which points nearly straight back from the sun, is also visible. This photograph was made with a 50mm lens at $f/2.8$, mounted piggyback on a telescope tube. Photograph by Brad Wallis. Above left: The inner five degrees of comet West's tail are shown in this 20 second exposure on Tri-X, obtained on the morning of March 6 using a 5-1/2 inch Celestron Schmidt. Note especially the small kink in the blue plasma tail. Photograph by Michael Moe. Above right: Nearly 15 degrees of the comet's tail are visible in a four minute exposure on Tri-X, made with a 135mm telephoto lens at $f/2.8$. This photograph, also taken on March 6, was shot from Acton, Calif. Compare these two black and white photographs with that taken through a standard 50mm lens, as shown at top left on page 24. Photograph by Robert Duriscoe.

broad daylight — one of only four comets in the 20th century that could be seen under such conditions.

Perihelion is the crucial point in any comet's behavior. Some comets have been known to increase tremendously in brightness after perihelion, while others have disappeared entirely. Still other comets are so disrupted by their swing past the sun that they break into sections and fall apart. The most famous instance of this phenomenon is comet Biela, which broke into two in 1846, was seen as a double comet in 1852, and disappeared thereafter — to be replaced by a meteor shower now known as the Andromedids.

There is simply no way of predicting with certainty what will happen to a comet after perihelion. Therefore, observers could do little more than hold their breaths and wait to see what comet West would do. The situation was not improved by adverse weather conditions that struck large sections of North America; some areas were clouded out for more than a week past perihelion, frustrating observers and, of course, making it impossible to view the comet's progress.

The first naked eye observations could be made on March 1 — and they showed that comet West had become incredibly bright. Rising only a few minutes



before the sun, the nucleus could be easily seen just above the horizon, glowing through the twilight. A short tail, about one degree in length, was also visible. Estimates of the total visual magnitude ranged from -1.0 to -0.5 — much brighter than the magnitude predicted for that date.

As the comet continued to draw away from the sun, it rapidly shifted its position relative to the background stars. The comet's consequent decrease in magnitude, however, was not nearly as swift a plunge as many comets experience, or as quick as originally estimated. The comet did not fall below first magnitude until about March 8 (the predicted brightness for that date had been third magnitude). One easy reference point for estimating the comet's brightness was the star Enif (Epsilon Pegasi). This star (magnitude 2.3) was situated close to comet West's head for several days on either side of March 7, allowing direct comparisons between the two and permitting more precise brightness estimates for the comet.

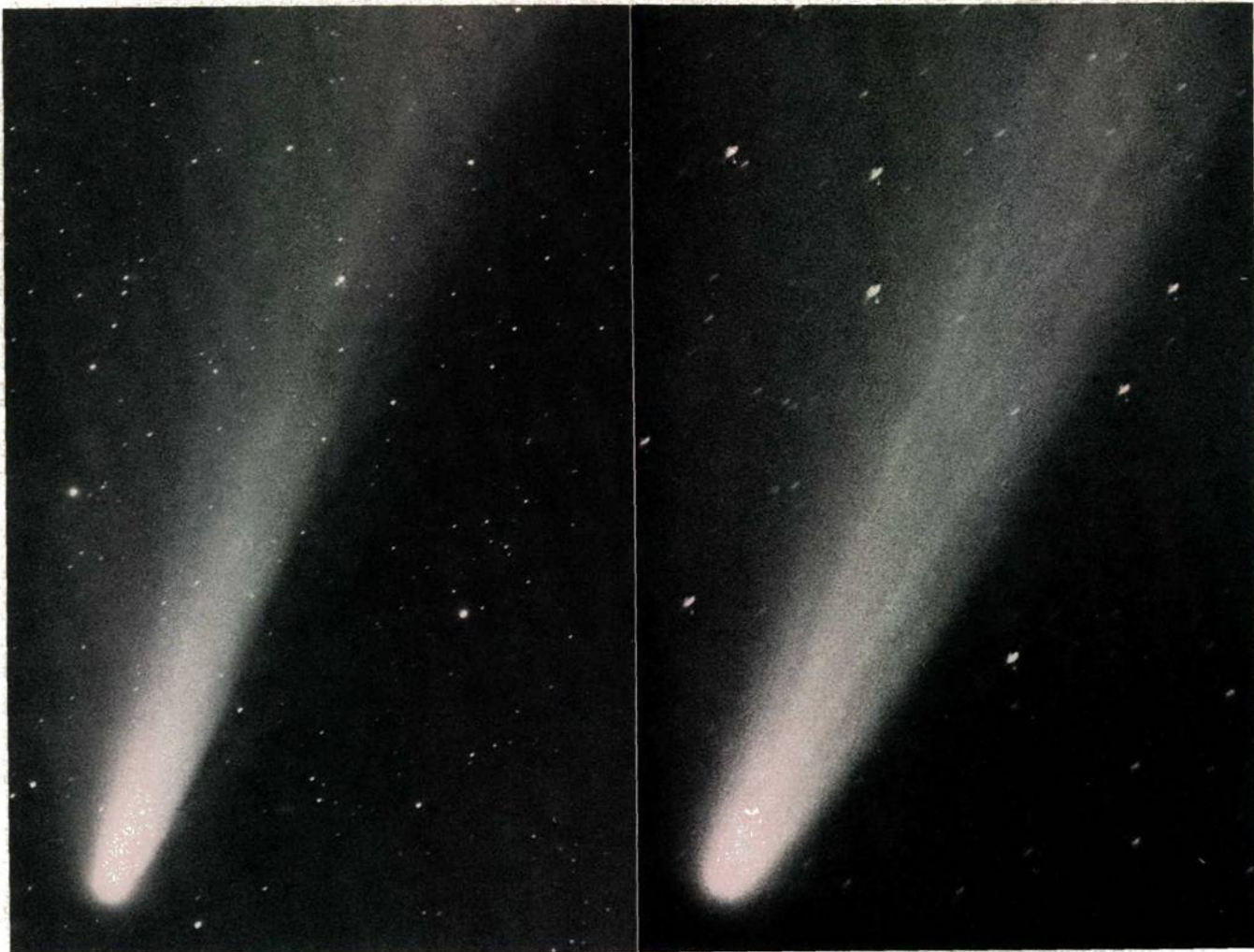
Comet West's magnificent tail began blossoming about March 2. On that date, the tail was more than 10 degrees long. By March 6 it had grown to 25 degrees; the following day it was 28. On the 8th, its tail was an incredible 30 degrees long, sweeping up from the nucleus near Enif through the constellations Equuleus, Delphinus, and into Cygnus almost as far as the northern cross. Under excellent ob-

Closely matched photographs made on different nights show fascinating changes in comet West's tail structure. The three second exposure (above left) was made on March 6, while the 2-1/2 minute exposure (right) was taken on March 8. Both were shot using a 55mm f/1.8 lens and Tri-X film. Although the overall appearance is similar, close inspection will reveal many differences. Photographs by Dennis Anderson. Opposite: From Big Bear, Calif., at an elevation of 7,000 feet, comet West was a stunning sight. With a tail stretching about 30 degrees — more than 40 million miles in space — it truly dominated the March 7 predawn sky. This 2-1/2 minute exposure on Kodak 103aF film was obtained with a 55mm lens at f/1.8. Compare the tail structure to that shown in the two photos above. Photograph by Michael O'Neal.

serving conditions, this entire length was visible to the naked eye. Long exposure photographs show it stretching even farther before its tenuous, outermost streamers became lost in the star clouds of the Milky Way.

The tail was in two parts: a bright, yellowish-white dust tail, and a smaller blue tail of ionized gas that extended straight back from the comet's nucleus. Many observers report seeing three or more tails: divisions in the broad, fan shaped dust tail produced this effect. Photographs of the comet showed a number of *synchronic bands* — parallel streamers in the dust tail thought to result from the simultaneous ejection of material from the nucleus. The cause of their formation, however, is still uncertain — especially because the bands do not join together at the nucleus. Comet West was the first comet to





display these prominent tail bands since Mrkos in 1957. After about March 9, the synchronic bands became weak and eventually diffused into a single, broad dust tail.

Spectral analysis of the blue gas tail revealed the presence of such elements as sodium, carbon monoxide, several ionized molecules, and a strong H-alpha emission. Radio telescopes noted an emission of hydroxyl (OH) molecules. The reason for the gas tail's blue color is the strong emissions of cyanogen (CN) taking place at the blue end of the spectrum.

Even in urban areas, where light pollution and smog cut down greatly on the amount of observation possible, comet West was a fine sight. The bright, starlike nucleus was quite prominent in the predawn sky by about March 6, and approximately two to three degrees of tail could be seen. The tail fanned out delicately from the nucleus, easily visible through such obscurations as haze and the green glow of mercury vapor lamps.

Comet West's brightness seemed to signify a fairly "healthy" comet. That this was not necessarily the case was shown by the observation, originally on the 5th, of a secondary nucleus that had apparently split off from the main section of the head. By the 11th, four separate nuclear conden-

Most of the photographs on these pages concentrate on the nucleus. Although the shots are necessarily overexposed to show tail structure, observatory photos show that the comet's head had split into four distinct sections by early March. Above left: This 2-1/2 minute exposure on Tri-X is a close-up of the innermost two degrees of the tail as seen on March 12. The generally lumpy structure underlies the streamers extending back from the nucleus. A five inch f/5 refractor was mounted piggyback on a larger scope for this shot. Photograph by A. W. Steinbrecher. Above right: Two days later, on March 14, the character of the inner tail had altered considerably. Strongly delineated streamers dominate the inner one degree of the tail. This six minute exposure on Kodak 103aF film was made at the Newtonian focus of an eight inch f/5 Coulter reflector. The photo was taken at Voorhees State Park in New Jersey. Photograph by Bob Kimmel. Opposite page, top left: This photograph, taken March 8 at the focus of the 10 inch f/6 Cave reflector at C.S. Morris Observatory, shows a central spike in comet West's tail. The field of view is approximately 1/4 degree. High Speed Ektachrome was pushed to ASA 400 for this shot. Photograph by Martin Stauffer. Above right: Comet West is beautifully recorded in this 10 minute exposure made at the focus of a home built six inch f/5 reflector. The shot covers a field of about two degrees and displays the dramatic separation of the gaseous tail (blue) and the dust and particle component of the tail (yellowish-white). This is a 10 minute exposure on GAF 200. Photograph by Robert Provin. Bottom: This four minute guided exposure on GAF 500 was taken through a 55mm f/1.8 lens; the camera was taped (as explained by the photographers) "mickey mouse" fashion to an Edmund mounting. Visually, three tails were visible when the photograph was obtained on March 8, since the split in the yellowish dust tail appeared to divide it into two parts; the blue tail of ionized gases is seen as the comet's third tail. The shot was taken from the Hieroglyphic Mountains in Arizona. Photograph by John Brandon and Jim Field.







On the morning of March 8, the head of comet West was between second and third magnitudes. The ragged blue tail of ionized gases and the smoother, grayer, yellowish dust tail show vividly in this close-up. The photograph, a 20 minute exposure on GAF 200 film, was made with a homebuilt six inch f/5 Newtonian and covers a two degree field of view — corresponding to about three million miles at comet West's distance. Photograph by Robert Provin. Above left: To the naked eye, comet West had an appearance similar to that shown in this photo taken on March 13. Note how markedly the comet's position relative to the stars had changed. This is an eight minute exposure on Fujichrome R-100 through a 50mm f/2 lens. Photograph by Greg Goodson. Above right: Guided by an eight inch Cave reflector, this exposure through a 135mm f/2.5 lens on High Speed Ektachrome shows the division of the tail into a clearly defined plasma tail and dust tail. Photograph by Marvin Mayo.

sations could be distinguished; in other words, the comet was breaking up. Severe disruption must have taken place at perihelion passage.

The original observation showed a separation between nucleus A (the main condensation) and nucleus B of about three seconds of arc. This distance had increased to 12 seconds by March 18. Nucleus C, located farther up the gas tail, was separated from A on the 18th by eight seconds of arc, while nucleus D was six seconds from A on the same date. The positions and motions of these separate condensations indicate that B was probably detached from A on Feb. 22, D split off from B on the perihelion date, and C (most likely a short-lived nucleus) separated from A on March 5. The nuclei will continue to move

apart as the comet leaves the sun's vicinity; by April 22, B is expected to lie a half minute of arc from nucleus A, while C should be almost a full minute of arc away from A by the same date.

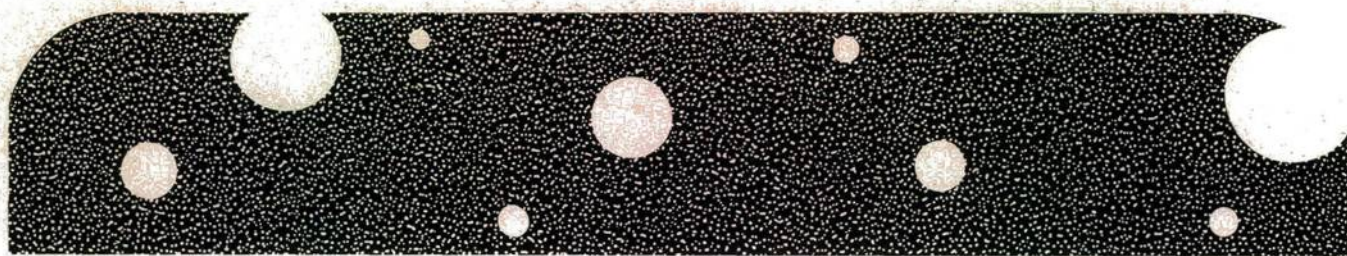
The nuclei, not all of the same brightness, differed from each other by two magnitudes in some observations. The nuclei are relatively slow moving — their motions can be calculated for some time into the future — and further disruption of the comet should not be of a violent nature.

How did comet West compare in brightness to other comets? It has been compared both favorably and unfavorably (depending on the observer) to comet Bennett of 1970. The latter did not approach the sun nearly as closely during its perihelion passage as did comet West, so it was almost always visible in a dark sky. On the other hand, since comet West was bright enough to be seen in broad daylight, it may have been intrinsically brighter than comet Bennett. Only three other comets this century could be seen in daylight — the last being Ikeya-Seki in 1965.

The photographs on these pages represent only a small fraction of the hundreds of excellent photos received by ASTRONOMY. The editors would like to extend their thanks to all who submitted photographs. If you requested return of your slides, we will return them as quickly as we can unless they are being retained for possible future use. ☛



sternbach



STELLAR FRONTIERS

Molecules of Life

by

Richard M. Lemmon

Astronomy and biochemistry are two disciplines which ordinarily wouldn't be seen in each other's company. But they've recently joined forces in an attempt to piece together one of humanity's most absorbing puzzles: the origin of life.

The key to the puzzle, and to life itself, is the carbon atom. The chemistry of life on Earth is essentially the chemistry of carbon compounds — so much so that the latter is often called organic chemistry. Living cells are composed almost entirely of water and carbon based molecules. The element's importance to life is highlighted by both astronomy and chemistry. Spectroscopic studies have shown that carbon is the fourth most abundant element in the universe, ranking only behind hydrogen,

helium and oxygen. Chemists have demonstrated that carbon has the unique ability to combine with other elements, as well as itself, to form a menagerie of compounds. Ninety percent of the several million known compounds are based on carbon.

Carbon compounds are usually less stable in the vicinity of heat and ultraviolet light than are compounds of other elements. As a result, scientists previously believed that organic compounds could accumulate only in rare, benign places in the universe where conditions were especially mild — such as the surface of a planet. Much of the laboratory research on prelife chemistry over the past 25 years has been based on this theory.

Earth is over 4½ billion years old, and the microfossil record (the remains of tiny, primitive organisms) shows that the first living cells appeared at least 3.4 billion years ago. What happened during those first billion-plus years that made life possible? Some of the answers may have been provided by laboratory research in biochemistry and studies in radio astronomy. Chemical compounds and processes in our galaxy discovered since 1968 by radio astronomers have profoundly changed humanity's perceptions of the origins of life.

Chemists have attempted to provide a scenario

Organic molecules — the basic constituents of life — have been detected in dense dust clouds close to the center of our Milky Way, such as the one depicted in the painting at left. The dust can absorb ultraviolet radiation that would tend to decompose the molecules, but radio waves easily pass through the dust. Radio telescopes on Earth can detect the molecules, either by their own emission of radio waves or by absorption of radio waves from stars hidden by the dust. Since dust clouds are the sites of stellar and planetary formation, the presence of organic compounds in the clouds is a good indication that life may be spread throughout the universe. Artwork by Rick Sternbach.

of the necessary-for-life chemistry that occurred on Earth before the appearance of life. There must have been a prior accumulation of the molecular building blocks of life — proteins and nucleic acids — before living cells could appear. This prelife chemistry, and the era during which it took place, is referred to as *chemical evolution*.

The composition of Earth's prebiological atmosphere was quite different from what it is today. Hydrogen dominates our universe — 85 percent of the universe's atoms are hydrogen atoms — so it is likely that just after Earth formed, its atmosphere was loaded with hydrogen and hydrogen compounds (ammonia, water and methane) instead of today's nitrogen, oxygen and carbon dioxide molecules. How, then, did the atmosphere evolve to its present composition? Hydrogen compounds most likely decomposed high in the atmosphere due to the solar bombardment of ultraviolet waves. The freed hydrogen, the lightest of the elements, escaped — an exiling process aided by Earth's relative warmth and low gravitational field. In contrast, the present atmospheres of the solar system's gas giants still consist mostly of hydrogen bonded compounds. Sometime between our planet's formation and the first appearance of life, a large amount of these same hydrogen containing compounds were present in the atmosphere.

In 1952, chemists Stanley Miller and Harold Urey performed a strikingly simple experiment with a gaseous mixture of hydrogen, ammonia, water and methane, the main constituents of Earth's ancient atmosphere. The chemists passed electric sparks

through this mixture to simulate the lightning that might have flashed through that primitive atmosphere. The unexpected result was the production of glycine and alanine, two amino acids (amino acids are individual units of proteins, biology's most important compounds). The Miller-Urey experiment demonstrated that the compounds necessary for life may have accumulated on our prebiological planet. Many "chemical evolution" experiments performed since 1952 have demonstrated the appearance of practically all the other key compounds of life. These experiments established the notion that there is little mystery about the origin of life. Given the inherent properties of matter and a planetary surface benevolent toward carbon compounds, the emergence of life seems inevitable. It is evident that Earth's life of 3.4 billion years ago could have evolved from the lifeless planet of 4.5 billion years ago.

By 1968, it appeared that chemical evolution explained the accumulation of organic compounds on Earth's surface. In that year, however, radio astronomy began making increasingly important contributions to our understanding of the organic (life-involved) chemistry of the universe.

Until the late 1930s, astronomers thought no molecules existed in the harsh environment of interstellar space. Only uncombined atoms — many stripped of some of their electrons — were believed to float aimlessly in space. Late in that decade, the 100 inch Mt. Wilson telescope detected new absorption lines in the visible and ultraviolet spectra of starlight. These were identified as the molec-

Discovered Interstellar Molecules

Year of Discovery	Molecule	Formula	Year of Discovery	Molecule	Formula
1937	Methyldiyne	CH	1971	Isocyanic acid	HNCO
1940	Cyanogen radical	CN	1971	Hydrogen isocyanide	HNC
1941	Methyldiyne ion	CH ⁺	1971	Methyl acetylene	CH ₃ C ₂ H
1963	Hydroxyl radical	OH	1971	Acetaldehyde	CH ₃ CHO
1968	Ammonia	NH ₃	1971	Thioformaldehyde	H ₂ CS
1968	Water vapor	H ₂ O	1972	Hydrogen sulfide	H ₂ S
1969	Formaldehyde	H ₂ CO	1972	Nitrogen sulfide	NS
1970	Carbon monoxide	CO	1972	Methanimine	H ₂ CNH
1970	Exogen	HCO ⁺ (?)	1973	Sulfur monoxide	SO
1970	Hydrogen	H ₂	1973	Ethynyl	C ₂ H
1970	Hydrogen cyanide	HCN	1973	Methylamine	CH ₃ NH ₂
1970	Cyanoacetylene	HC ₃ N	1974	Dimethyl ether	(CH ₃) ₂ O
1970	Methanol	CH ₃ OH	1974	Methyl formate	HCOOCH ₃
1970	Formic acid	HCOOH	1974	Ethyl alcohol	C ₂ H ₅ OH
1971	Carbon monosulfide	CS	1974	Silicon sulfide	SiS
1971	Formamide	NH ₂ CHO	1975	Vinyl cyanide	CH ₂ CHCN
1971	Silicon monoxide	SiO	1975	Sulfur dioxide	SO ₂
1971	Carbonyl sulfide	OCS	1975	(Unnamed ion)	N ₂ H ⁺
1971	Methyl cyanide	CH ₃ CN	1975	Cyanamide	NH ₂ CN
			1975	Formyl radical	HCO

Chemistry in Space by Dale F. Dickinson

The richness of the interstellar medium raises unexpected questions about the chemistry of space. How can complex molecules such as acetaldehyde and cyanoacetylene form in clouds so rarified that a chance collision between atomic species is too infrequent to account even for the low densities observed?

One of the most widely touted ideas is called *grain catalysis*. Interstellar molecules tend to concentrate in regions that appear dark in optical photographs — regions heavy with cosmic dust grains. These grains may be silicates, or perhaps graphite or other substances; but we really don't know their composition. Studies of their absorption of background starlight show that the size of a typical dust grain is about 1/50,000 inch. This is extremely small, but mountainous when compared to molecular dimensions. Although collisions between molecules may be rare, molecular collision with giant dust grains must be more common. The grains act like flypaper to which molecules readily stick.

The details of the grains' surface chemistry is still poorly understood, but there are ways in which molecular fragments can bind themselves to grains. So-called saturated molecules (all of whose electrons are chemically paired off) will stick because of weak electrical forces, known as Van der Waals forces. Atoms and molecules with unpaired electrons (molecules in this state are called radicals) are chemically more active than saturated compounds, and will easily attach to the edges of grains where electron-pairing occurs most easily. (This is somewhat analogous to the way in which crystals grow.) Grains also slow the molecules they collide with, absorbing excess energy and momentum which might otherwise cause them to collide without combining.

Molecules in space may also be made by collisions involving *ionized* atoms and molecules — those that have lost an electron or picked up an additional one, thereby upsetting their nominal balance of positive and negative charges. Ions have a much larger cross section (they "look bigger") than their nonionized counterparts because their electric forces are stronger and extend further. They are thus more likely to collide with other molecules and chemically combine. The primary way that electrons become disengaged from molecules is probably from cosmic rays that could knock off loosely bound electrons. An atom would thereby be ionized, providing a free electron which can get stuck to another atom.

Some molecules are manufactured in the atmospheres of stars and spewed into the interstellar medium by cataclysmic events such as supernovae, novae or pulsating stars. No reliable figures exist for this process, but the number of molecules generated in this way is probably small.

The testing of these competing processes is only now beginning. At present there is some slight evidence that ion-molecule reactions may be dominant, but it will be some time before we can satisfactorily understand molecule formation. ➤

ular radicals cyanogen and methylidyne (two forms of methylidyne were discovered, one ionized). Until the advent of radio astronomy, this was the entire list of interstellar molecules, and it didn't change the notion that space was a region rather devoid of chemistry.

Rapidly improving radio astronomy equipment and techniques soon brought about a revolution in astronomical ideas. These improvements led to the discovery of organic molecules in the core area of the Milky Way.

Dense dust clouds containing a large fraction — perhaps as much as 50 percent — of our galaxy's matter are situated close to the center of the Milky Way. The dust is mainly composed of extremely small particles whose composition is not known for certain; they may be silicates and carbides. The dust plays a key role in preserving the organic molecules found there: Ultraviolet light, which tends to decompose organic molecules, cannot deeply penetrate these clouds.

In contrast, the dust does not appreciably absorb radio waves. Radio telescopes can detect organic molecules in two ways — either by the molecules' absorption of radio waves emitted by stars veiled by the dust cloud, or by the molecules' emission of radio waves after colliding with hydrogen atoms. Molecules may also emit radio waves by absorbing as well as re-emitting a portion of the universe's pervasive background radiation believed to be left over from the big bang that created our universe. A given compound can be identified by comparing the frequencies received by the radio telescope with the compound's frequencies directly measured in a laboratory on Earth.

Soon after reports of the interstellar presence of ammonia and water, the first true organic molecule, formaldehyde, was detected in several regions toward the center of our galaxy. These discoveries demonstrated that polyatomic molecules could exist in the oppressive environment of interstellar space. Interest was focused, more importantly, on the fact

that these three molecules (formaldehyde taking the place of methane) form a mixture that supplies many biologically important molecules when subjected to electric discharges in a Miller-Urey type of experiment. Astronomers and organic chemists had, for the first time, a common professional interest. Because organic molecules are excellent transmitters of information about such conditions as temperature, pressure and radiation intensities in interstellar space, these molecules present fascinating clues about the ultimate origins of life. They also indicate that life may well be spread throughout the universe.

We now know that molecules with as many as nine atoms exist in interstellar space. When capabilities and sensitivities of radio telescopes are increased, we will probably be able to find additional, more complicated molecules. Obviously, complicated biomolecules do not exist merely at mild locales, such as Earth's surface. They are evidently scattered throughout our galaxy, and probably other galaxies, in huge amounts. And, they are not densely packed; concentrations in interstellar space are less than one molecule per cubic inch — a far better vacuum than any manufactured on Earth. But space is so vast that the actual numbers of these molecules are enormous. For example, the amount of ethanol in the dust cloud where it was found (Sagittarius B2) has a total mass close to that of the sun.

Materials such as dust grains tend to collect organic molecules on their surfaces. In addition, interstellar dust clouds appear to be places where new stars and planets are being formed. It seems likely that newly formed planets will be found with life precursor chemicals already on hand. The development of life on a planet would not have to await the slow accumulation of amino acids and proteins from some primitive atmosphere of methane, hydrogen, water and ammonia.

The huge amounts of organic molecules spread throughout space add to the likelihood that life is scattered across the universe. Ten years ago the supposition that life existed elsewhere in the universe was based on the probability that Earth-like planets existed around other stars. Finding life's key building blocks spread throughout our galaxy gives a tremendous boost to the possibility that life exists elsewhere.

The integrated fusion of astronomy and biochemistry has merely posited that life exists beyond the atmosphere of our planet. The active search for evidence still lies ahead. 

Dr. Richard M. Lemmon is associate director of the Laboratory of Chemical Biodynamics at the University of California-Berkeley. A member of the National Council of the American Chemical Society, he has done research in the area of chemical evolution for over a decade.

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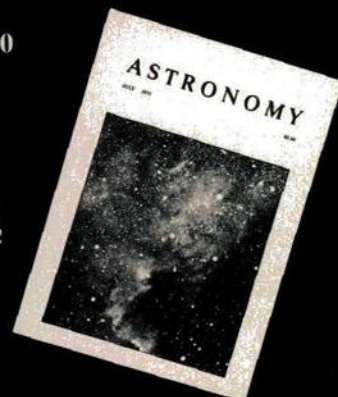
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GAZER'S GAZETTE

Observing Galaxies

by Richard Berry

Galaxies are almost always a big disappointment for persons just starting observational astronomy. Where are those intricate spiral arms? Where are all the billions of stars living and dying? And why do galaxies have to be so frustratingly faint? Nobody ever comes right out and says that galaxies are a waste of time, but many beginners, not knowing what to expect, lose their initial enthusiasm and drift off to other things like lunar observing. At least they can see the moon.

If you haven't yet gotten discouraged and are still eager to find galaxies, May and June are the best months to view them. The brilliant winter constellations are gone, and the Milky Way, with its galaxy-obscuring dust and gas, does not rise until late at night. Indeed, astronomer Edwin Hubble christened the area on either side of the galactic plane the "zone of avoidance", to indicate the absence of galaxies from this region.

But filling the rest of the night sky is a vast window into extragalactic space. When you look overhead, you're looking nearly straight out from the plane of our galaxy into the space beyond. It is in this space that you'll find the great majority of external galaxies.

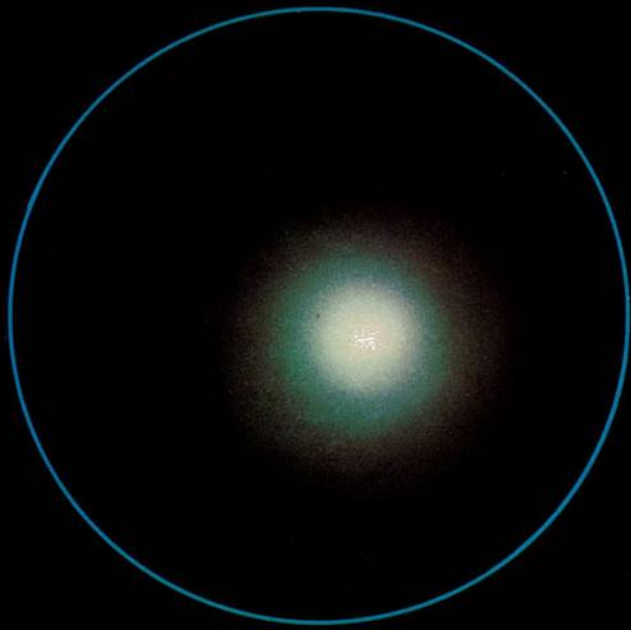
It's true that galaxies are among the most difficult classes of sky objects to observe. That difficulty is even more frustrating because photographs taken with the world's biggest telescopes on sophisticated photographic emulsions show them so well. Why is something that looks so spectacular on a photograph such a letdown through the telescope? Think for a few moments and the answer will be clear. On the average, galaxies are more or less like

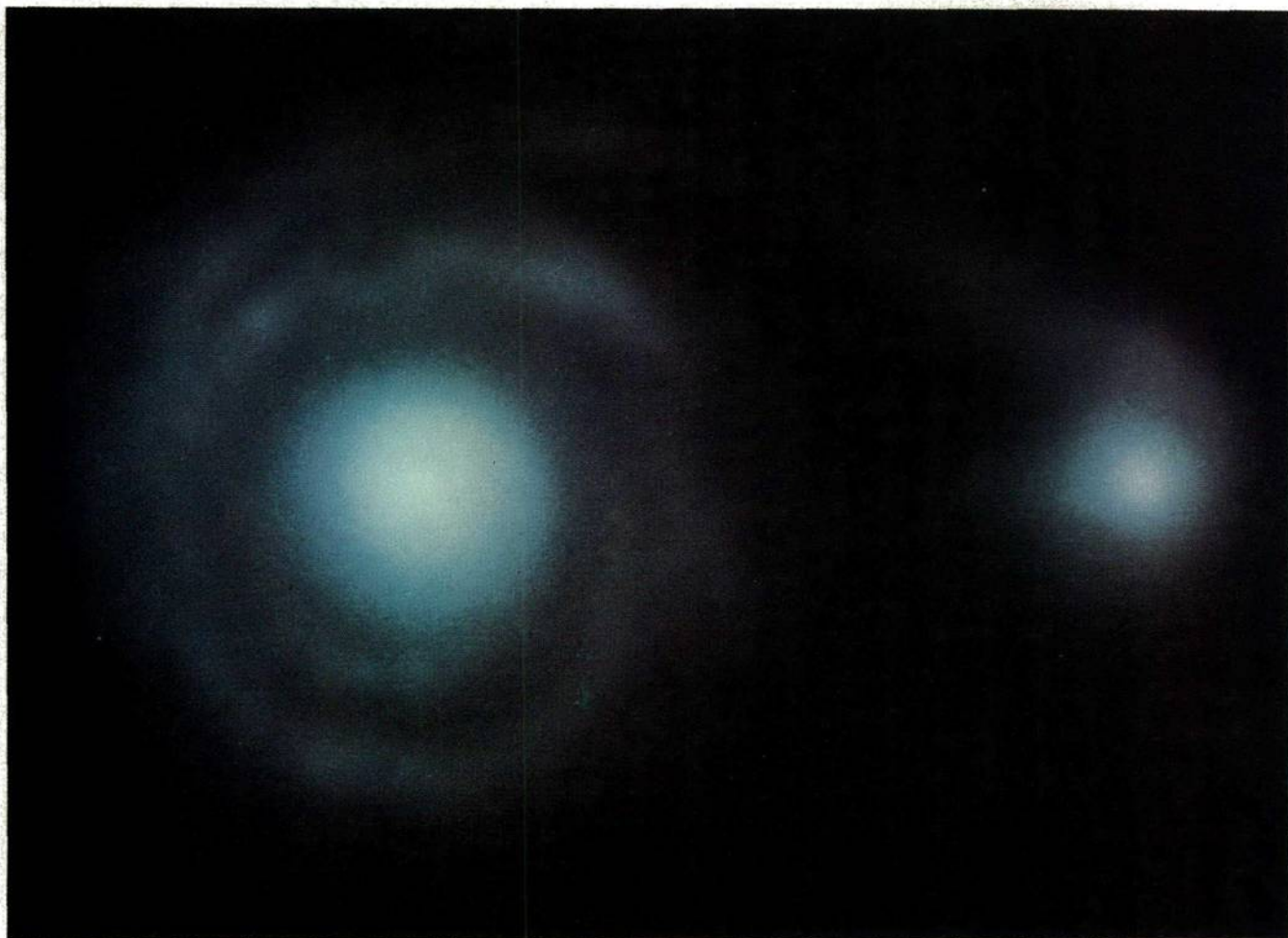
the Milky Way — mostly empty space. The average space between stars in the sun's neighborhood is a few light-years, or several trillion miles. This is a large enough space to spread a star's light pretty thin, and it's the reason for the Milky Way's dimness; the stars may appear closely packed, but they are separated by large spaces. Similarly, when we see another galaxy, we are looking at another area made up of mostly empty space. In a galaxy's nuclear bulge, the stars are more condensed, and you can easily see in your telescope that the nucleus is the brightest part of the galaxy.

Because they're faint, galaxies are easily obscured by the least amount of light pollution or haze. If you want to look for more than the brightest few, you'll need a good observing site. One way to judge your site for galaxy hunting is by the appearance of the Milky Way. If you can just barely see the Milky Way, you'll be able to find galaxies pretty well though you won't see any detail. If you can see the Milky Way easily, you'll be able to make out the spiral arms on a dozen of the more prominent galaxies through a six inch telescope. And if you can't see the Milky Way at all, you'll only be able to find the brightest galaxies.

In addition to being faint, galaxies have small

The visual appearances of galaxies through the telescope are not the same as long exposure observatory photographs. In this diagram are shown several examples of different types of galaxies as seen through a six to eight inch telescope under high power. In the left column are edge-on, tilted, and face-on spiral galaxies. At bottom right is an elliptical galaxy; the Sombrero galaxy (M-104) is shown at right center, and M-31 is seen at upper right. Artwork by Victor Costanzo.





angular diameters. Most of those on the Messier list are only a few minutes of arc across — much larger than planetary disks, but a good deal fainter. This makes galaxy observing even more difficult: If you use a low power eyepiece to obtain a bright image, galaxies are too small to see well; if you work with higher power, they're too faint. One reason that a large telescope, like a 12 inch, gives a good view of galaxies, is that the lowest power on such a large scope magnifies enough to show details.

So, you won't be able to see galaxies the way you see them in pictures. The main problem is with your eyes. Galaxies aren't much brighter than the background light of the sky, which includes light from the Milky Way, from dust inside the solar system, and light emitted by Earth's atmosphere. The contrast between a galaxy and the surrounding sky is low, and the eye is not very sensitive to contrast at low light levels — and still less to contrast over small angles. Even though the image in your telescope is sharp enough to enable you to see spiral arms, the limitation occurs at your eye. Averted vision and slight jiggling of the telescope help you discriminate contrast at low light levels — enough for you to make out general outlines, but not enough to see detail.

Film, on the other hand, is not as much a problem as your eyes. The right film will record the same picture of an object whether a short exposure is

used in bright light or a long exposure with faint light. Thus, a good photograph of a galaxy taken with a six inch telescope inevitably shows more galactic structure than the eye can see through the same instrument.

What type of telescopic equipment do you need to see galaxies? The brightest one — M-31 in Andromeda — can be seen without optical aid. If you have a good observing site away from city lights and haze, 7 x 35 binoculars will reveal about a dozen bright galaxies as faint fuzzy patches of light. You can probably see all the galaxies listed in the Messier catalogue through a 2.4 inch refractor. But you shouldn't expect to be able to go beyond mere identification; even M-31 appears as a dull oval with a brighter, nearly circular center. The smaller, fainter galaxies — like those in the Virgo cluster (see "The Realm of the Galaxies", *ASTRONOMY*, June 1975) — will be no more than slight smudges that can become lost under the slightest haze. Don't be disappointed; look at them again, more carefully. You



This photograph is one of the best non-professional pictures of the Whirlpool galaxy in existence. Compare this photo with the galaxy's visual appearance on the opposite page; the spiral arms are more detailed, and the stream of stars, gas and dust connecting the main galaxy to its companion is more easily seen in the photograph than through the telescope. This is a 20 minute exposure on Tri-X film. Photograph by Leo C. Henzl Jr.

can make out overall shapes fairly well with a 2.4 inch, and these shapes are not all the same. Some "light smudges" are nearly round with a fairly uniform surface brightness, while others have a tight, round little core with a faint round halo. Some, like M-31, are oval, and still others have narrow spindle shapes. These are the basic distinctions between types of galaxies: Elliptical galaxies are those with fairly uniform brightness; spirals have a bright core and a fainter halo. If a spiral is seen face-on, the halo will be round; if the galactic disk is seen edge-on, the halo will be oval.

A six inch telescope puts you in the ranks of "big time" galaxy hunters. Even from moderately murky suburban skies, all the galaxies on Messier's list are accessible to you — as well as a good many others that Messier missed. Use low power (about 40 to 60) to find a galaxy, and then switch to a higher power — up to a few hundred — for close examination. If you have an excellent site, after your eyes are fully dark adapted you should be able to see spi-

ral structure in about a dozen of the larger galaxies — especially in M-31, M-51, M-101, and a few of the spirals in the Virgo cluster. You won't see the massive spiral arms shown in observatory photographs: Spiral structure is subtle and delicate, requiring techniques such as averted vision and telescope-jiggling. If you observe from the city or suburbs, a six inch scope probably won't be large enough to detect spiral structure, but a 10 or 12 inch aperture will usually be adequate.

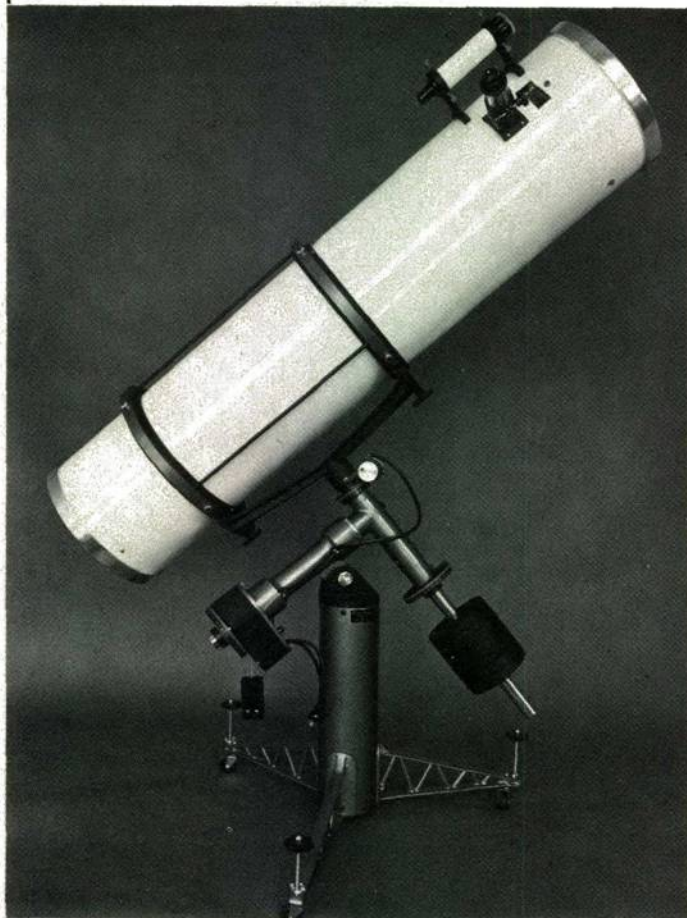
With a six inch, elliptical galaxies will be fuzzballs — but remember that ellipticals are nothing more than fuzzballs at any aperture. A few of the edge-on spirals (such as NGC-4565, NGC-891 and M-104) have plainly visible dust lanes, which means you can see a dark line crossing the galaxy.

Perhaps the reason some observers dislike galaxies is that they don't realize what they are seeing. Naturally, a faint fuzzy dot of light is a visual disappointment. It's only when you understand the scale, the incredible distances, the physics and astronomy involved, that you can look at a faint light and see a galaxy. Galaxies have to become a state of mind. You can't expect to have the universe laid out before your eyes; you must bring an active mind to the telescope. The faint blobs of light that are galaxies can activate appreciation of how each type of galaxy — each object — fits into the scheme of the universe. 

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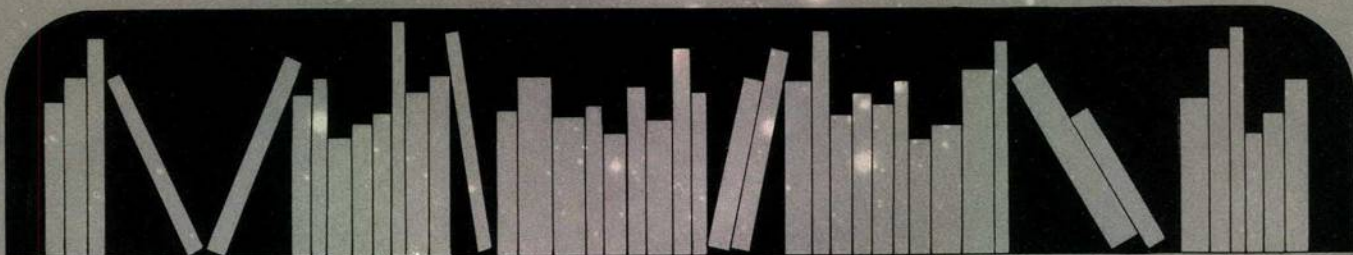
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The Future of the U.S. Space Program

by ARTHUR L. LEVINE

248 pages, hardcover, \$16.50
Praeger Publishers (1975)

At first glance this book may seem to be another chronicle of future space miracles in the 1980s. It is not. But it may be a more important subject for the real future of the space program.

The book deals with policy and policy making. Who decides what should be done in space, and for what reasons? What costs, potential discoveries, possible difficulties, and probably consequences must be balanced before a project is approved, delayed or canceled? Who gives advice, and who makes the ultimate decision?

The obvious answer is NASA, and the obvious answer is wrong. Most of America's space program was born in Congress and the White House; many potentially rewarding space projects have recently died there. The actual procedures are chronicled, explained and predicted for the future.

This topic sounds dull and uninspiring to most scientists, and the results have been predictable. Scientists have had poor communications with Congress and have lately had bad luck in getting important projects approved. Space astronomy has been a particularly heavy loser. So these lessons may be of more relevance to astronomy than is at first obvious.

The author is a political analyst and not an engineer, so the book suffers from a few technical errors. For example, the Apollo 1 fire in 1967 probably did not "delay the moon landing 18 months" since other critical space equipment like the Lunar Module and the S-II rocket stage were also lagging badly and would not have been ready until mid-1969 anyway. Nor is pure oxygen "highly combustible" — it does not burn at all, but it does make most other materials highly combustible in its presence.

Furthermore, the author falls for a grand deception now being foisted on the world by Soviet propagandists and

independently by certain Western liberal circles: the notion that Moscow was never really interested in racing America to the moon at all. In fact, the Russians tried very hard to send men to the moon before the Americans, and spent a great deal of money on their efforts. They did not succeed due to their technological shortcomings, but they are very good at coverups and re-writing history.

Tables of budget figures are dull, but they presage space headlines of two years in the future. If there is to be any future space program at all, people who want to help that future must learn as much about space policy making as they know about space vehicle making. This book explains clearly that much ignored area of space exploration, and many people (astronomers included) had better learn these lessons. *James E. Oberg.*

The Dark Night Sky

by DONALD D. CLAYTON

206 pages (illus.), hardcover \$9.95
Quadrangle/New York Times Book Co. (1975)

Donald Clayton is a fairly prominent young scientist; in this book he apparently intends to convey some of the excitement he has derived from his intellectual pursuits. In other words, the book is a confessional: "Why I am an astrophysicist." Clayton perceives intense excitement, romance and wonderment in nature, but generally fails in his attempt to convey this excitement to the reader.

The chief problems with this book are that Clayton has not determined who his audience is — so his style varies between being oversimplified and technical — and has not decided what sort of writer he wants to be, so the tone also varies. He vacillates among being instructive, personal, and poetic.

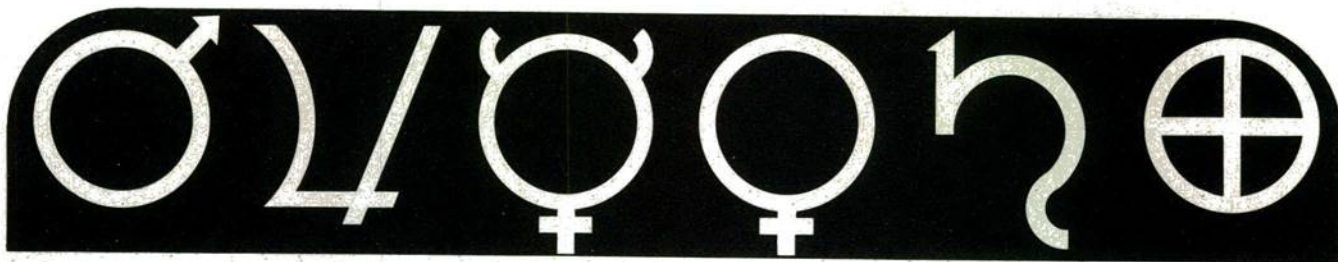
Content of the book is very diverse. Chapters deal with Stonehenge; Copernicus and Newton; Loys de Cheseaux, an obscure 18th century Swiss who was the true originator of "Olbers' paradox"; the question of why the night sky is dark; Einstein and relativity (here, Clayton uses an analogy with baseball, and in his imaginary game there is a pitcher called Lefty Einstein).

At times, *The Dark Night Sky* seems more a history of the science than the history of Clayton's personal love affair with that science. Even within a chapter, the turns of thought are dizzyingly abrupt; One moment we are in Cambridge, and the next we are bending over a dead deer beside a Texas road.

To at least a slight degree, the book seems to beat a personal drum for Clayton. The reader occasionally gets the impression that Clayton is standing at the very pivot of science and its history. As an example of his concept of the relative importance of things: "Fate arranged it that I was married in that same city where Einstein's most beautiful thoughts were hatched." Even if history does rank Clayton with Einstein, his marriage might not prove worthy of note.

Clayton does succeed in offering some new insights into the intellectual and romantic excitement of certain facts and ideas. For instance, he thinks of Mars features when he beholds certain geological formations on Earth, and he offers some interesting ideas on the relevance of the physical concept of entropy to the idea of an expanding universe. But, insofar as ASTRONOMY readers probably are already convinced of the interest and importance of astronomical research, for them the book may be preaching to the already-converted.

This is not an uninteresting book, and it is readable. But the maddening lack of any organizational thread for the reader to grasp detracts considerably. *Richard Stein.*



SKY ALMANAC

Neptune Takes A Bow

Every few years the planets tend to cluster together as seen from Earth, and they are all visible at once. While this state of affairs makes planetary observers happy, it also unfortunately means there will be a time during the same year when no planets will be seen in the sky. We are reaching such a point now; most of the planets are leaving, or have already left, the May sky, and this situation will be even worse during the early summer. Solar system specialists will have to be content primarily with Neptune and a bright meteor shower this month.

Neptune

The eighth planet from the sun, Neptune can perhaps lay claim to the dubious distinction of being the most neglected by observers of all the major planets. Everyone notices the bright planets, of course, and Uranus is easily seen in binoculars; Pluto is dim and hard to spot, and many observers try to find it for those very reasons. But Neptune lies in a sort of halfway house between Uranus and Pluto — not as bright as one, and not as challenging as the other.

During this entire year, Neptune will be located in Ophiuchus — a constellation that, although not usually included as one of the “official” zodiacal constellations, contains a generous slice of the ecliptic within its borders. The planet reaches opposition on June 2; its magnitude will be +7.7, so you’ll be able to see it as a starlike dot through a small telescope. There are no stars brighter than fifth magnitude along Neptune’s 1976 path (see the map on page 45), and this lack of a suitable “guide star” may make it a little difficult to find. Like Uranus, Neptune has a green color; but Neptune is more distant and less bright than Uranus, so the color is not nearly as pronounced.

It takes Neptune almost 165 years to travel once around the sun, which means that the planet has yet to complete its first orbit since its 1846 discovery. It moves only about 2.2 degrees across the sky an-

nually. Neptune travels so slowly because it’s so far away; its average distance from the sun is 2.8 billion miles. Interestingly, Neptune has one of the most circular orbits of any of the planets. Its aphelion and perihelion distances do not vary greatly, and only Venus’ orbit has a lower eccentricity.

If you want to see more of Neptune than a single point of light, you’ll need at least a six inch telescope. An instrument of this size is barely large enough to show Neptune’s disk — the diameter of which is only 2.5 seconds of arc. Even with wider apertures, though, the disk is about all you’ll see; the planet is too far away for any surface detail to be distinguished.

Mercury

After its very favorable elongation at the end of April, Mercury can still be seen low above the western horizon during the first few days of this month. The planet is fading rapidly, however, and drops to magnitude +1.5 by May 7. By the 10th it will no longer be visible, and on May 20 it will be in conjunction with the sun. The next good opportunity for observing the smallest planet this year will come in October.

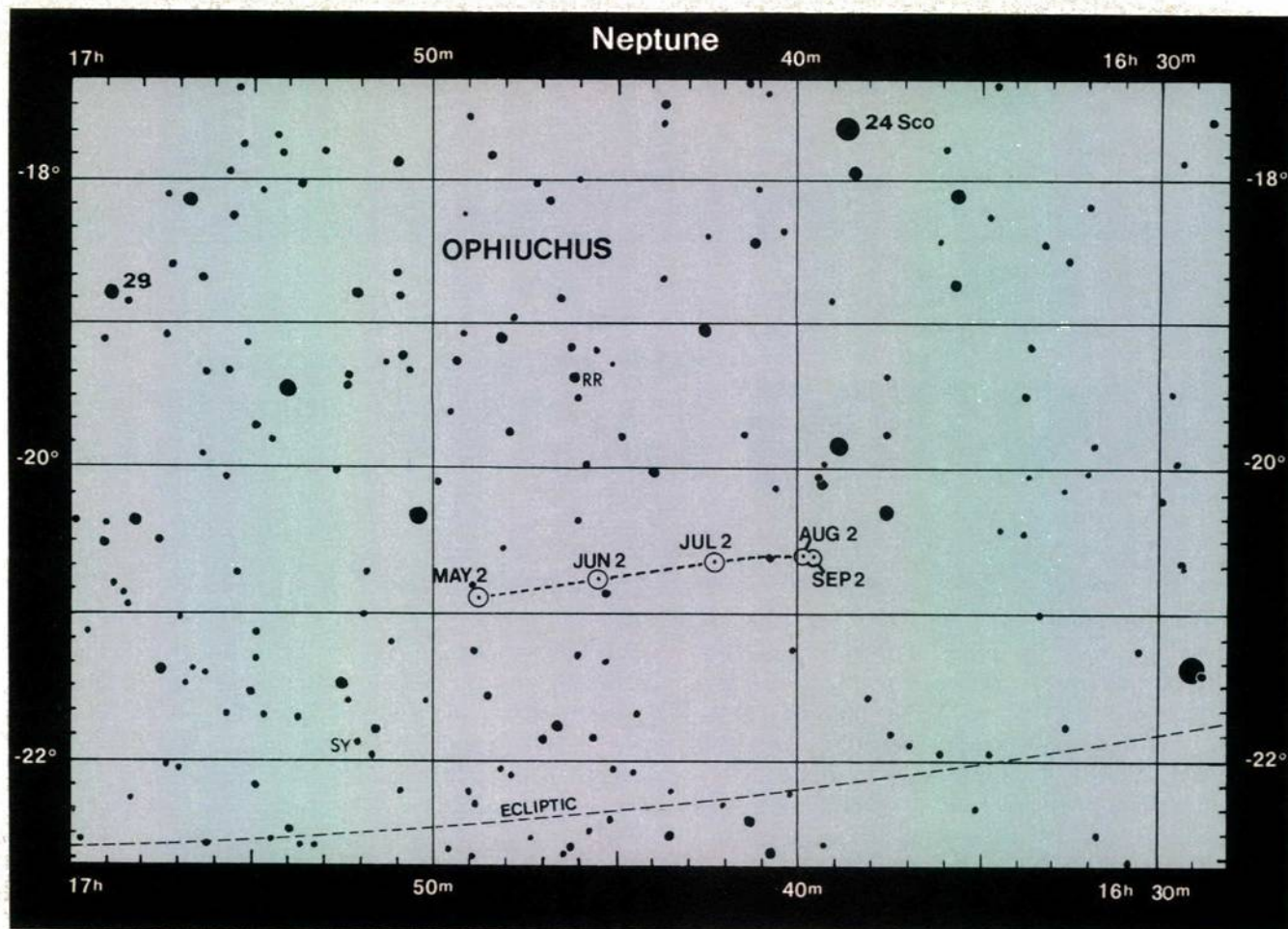
Venus

Venus draws ever closer to the sun during May. Keen-eyed observers can see the -3.3 magnitude planet rising only a few minutes before the sun for most of the month. By the end of May, Venus will be in nearly full phase, but its small size (less than five

The crescent moon is only 35 hours old in the photograph at top left on the opposite page. A Celestron 8 at f/10 was used for this two second exposure on Fujichrome R-100. Photograph by Stephen Reed. Crux, the southern cross, gleams in the photograph at top right, obtained from Victoria, Australia. Also visible to the east of the cross are Alpha and Beta Centauri; south of Crux is the constellation Musca. The 15 second exposure on High Speed Ektachrome was taken through a 50mm lens at f/1.4. Photograph by Dana Franz. M-7 (bottom), a brilliant open cluster in Scorpius, is visible to the naked eye. This is a 20 minute exposure obtained with a home built six inch reflector at f/6; the film used was GAF 200. Photograph by Brad Wallis.







Photos of two southern hemisphere emission nebulae are reproduced on the opposite page. The Lagoon nebula (M-8) is seen in a 20 minute exposure on Fujichrome film, taken through an eight inch reflector at f/5. Photograph by Pat Michaud. The Eta Carinae nebula, at the center of the southern Milky Way, was photographed from Hawaii. A 50mm lens at f/2 was used for this 20 minute exposure on GAF 500. Photograph by Clifford Livermore. The planet Neptune will be in a favorable position for observing throughout the summer; the map above gives its location at monthly intervals. Opposition is on June 2. Map by Bruce Johnson.

seconds of arc in diameter) and nearness to the sun will prevent useful observation.

Mars

Now a second magnitude object, Mars is not bright enough to be prominent during the rest of 1976. It travels rapidly through the sky, moving from Gemini into Cancer on the 10th. At about 10 p.m. EDT on May 11, Mars will be only 1.3 degrees from Saturn. Both planets are well below maximum brightness, but the conjunction will still be an interesting sight, eminently suitable for photography through wide-angle lenses or telescopes at low power. Mars' diameter shrinks during May from 5.5 to 4.8 seconds of arc as its distance from Earth increases from 157 to 181 million miles. On the 21st, the planet reaches aphelion — its farthest distance from the sun (155 million miles).

Jupiter

Just past conjunction, Jupiter is too close to the sun to be easily seen for most of May. During

the last few days of the month, it will be a morning star rising shortly before the sun.

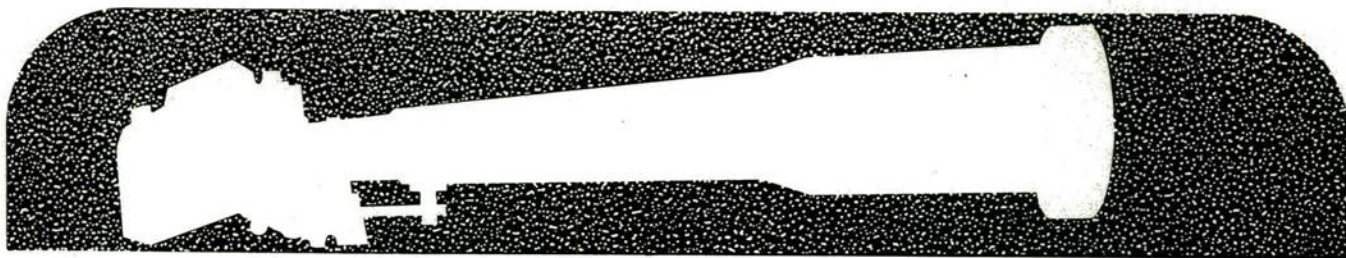
Saturn

Saturn is going down in the west at sunset and sets about midnight. In Cancer, the ringed planet is by far the brightest object in that faintest of all zodiacal constellations; its magnitude is +0.5 during most of May. Saturn continues to head away from Earth, increasing its distance from 862 to 903 million miles.

Eta Aquarid Meteors

After last month's disappointment with the Lyrids, meteor shower watchers will be pleased to know that the moon will not interfere with observation of the Eta Aquarids. On May 5, when the shower is at its peak, the moon will not yet have reached first quarter phase and will set before midnight. The shower's radiant point, situated almost exactly on the celestial equator, is near the fourth magnitude star Eta Aquarii, and will rise after midnight on May 5.

The Eta Aquarids are a rich shower, apparently following the path of Halley's comet. The typical meteor in this shower is fast moving, and leaves a long glowing trail that persists for a few seconds after the meteor burns up in the atmosphere. At their peak, an average of one meteor every four minutes is common. Being bright and swift, they are excellent subjects for photography. ☾



PHOTOGRAPHY IN ASTRONOMY

Choosing B&W Films

by

Dave Hudgins and Greg Griffith

Astrophotographers know that film selection can make the difference between mediocre results and spectacular photographs. While only a few color films are suitable for astrophotography, you can choose from about a dozen black and white films — each of which has diverse and powerful recording abilities unmatched by color films. Several of the black and white films available are made specifically for astronomical use, and two of them have special applications for city dwellers in alleviating light pollution problems. The additional advantages of low cost and easy home processing make black and white photography attractive to beginners and advanced astrophotographers alike.

Of the dozen black and white films available, how can you determine which will give the best results? The first step is to recognize that each of the three major types of sky shooting requires something different from the photographic emulsion. Film characteristics required for short exposure meteor and fixed camera constellation photography are different from those needed for long exposure, deep sky work; still other requirements must be met for high resolution lunar and planetary photography. To get the best pictures, you must be aware of differences in contrast, grain size, color sensitivity, and overall speed of the various films available. With a little experience, you can soon match your equipment and astronomical subject to the best film for the job.

All the films mentioned in this article are available at camera stores or through mail order dealers. The films are comparable in price but vary somewhat in ease of purchase, storage and processing.

Constellation and Meteor Photography

Fixed camera constellation and meteor photography has one overwhelmingly important film re-

quirement — high speed. Thirty seconds is about the limit in constellation shots if you want to avoid star trailing, and meteors blaze for even less time. In both cases you need the most sensitive films available, even at the expense of coarse grain. Films with ASA ratings of 400 or higher are most suitable for this type of sky shooting.

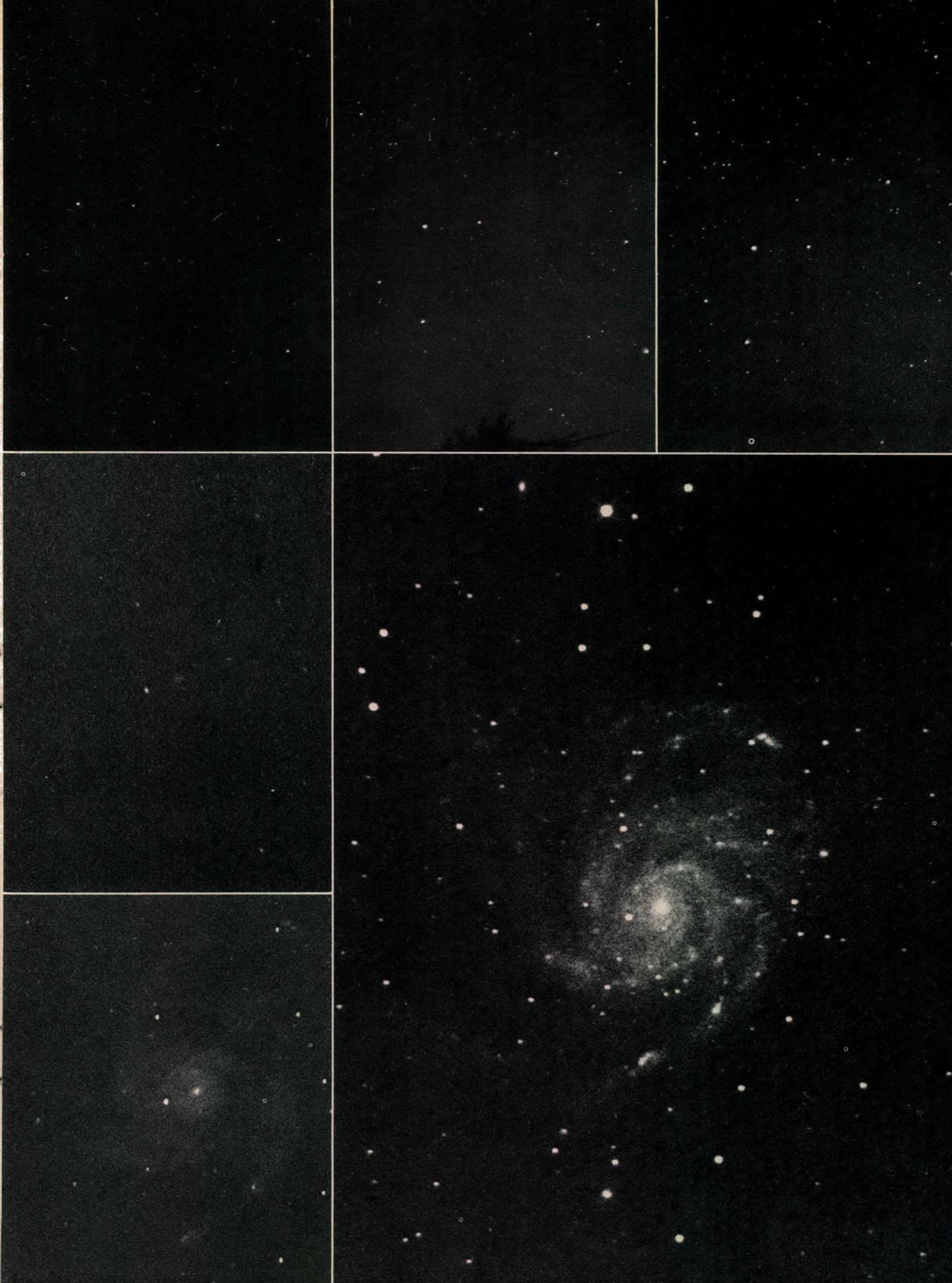
For 35mm cameras, the fastest readily available films are Tri-X and 2475 Recording Film, which have normal ASA ratings of 400 and 1200 respectively. Both these films are excellent for meteor photography, but Tri-X is a much better choice for constellation shots than 2475. Though very fast for exposures of two seconds or less, 2475 does little additional image recording during the remainder of a 20 or 30 second constellation shot.

If you use a 120 size camera (2-1/4" x 2-1/4" negatives), you could use Tri-X; but a much faster film known as Royal-X Pan (ASA 1250) gives better results. Royal-X is a rather grainy film, but this disadvantage is easily outweighed by its high speed — an important consideration for 120 size cameras since they usually have relatively slow f/3.5 lenses.

Of course, all films can be pushed to some extent when you process them yourself. By developing for an extra long time, you'll get higher speed; faint stars will appear that otherwise wouldn't have shown, but you will pay a price with a grainier image and increased film fogging.

Fixed camera constellation shots illustrate the kind of results you'll get using a variety of black and white films. Obviously, some of these films

Exposures of 20 seconds with three films are compared here. Taken with a 35mm SLR with a 55mm f/1.7 lens, the exposures in the top row are: left, Plus-X; middle, Tri-X; right, 103aE. Below, 20 minute exposures show the effects of reciprocity failure with different films: left upper, 2475 Recording Film; left lower, Tri-X; right, 103aE. These shots were taken with a 12 inch f/4.5 reflector at Newtonian focus. Photographs by Greg Griffith.



produce better results than others; the poor results from 2475 Recording Film are especially striking. In a 30 second exposure, the more effective films such as Tri-X record stars down to magnitude 7.2 — about three times dimmer than the naked eye can see!

Deep Sky Photography

Many photographers derive their greatest pleasure from the challenge of deep sky photography — capturing distant nebulae, galaxies and star clusters on film. Unlike constellation or planetary photography, deep sky objects are extremely dim — often appearing as nothing more than a formless glow in small telescopes. Only the cumulative recording power of photographic film in a long exposure allows us to record and study these objects.

Film requirements for deep sky work are the most demanding for any type of astrophotography. Because of the dimness of the subject, you'll generally need long exposures to build up an adequate image on the film. But long exposures bring out the most serious problem with conventional films: They don't continue to build up an image after the first few minutes of exposure. The effect is known as *reciprocity failure*. Some films that are normally considered very fast (such as 2475 Recording Film) become extremely insensitive during long exposures.

The graph on page 51 compares the long exposure recording power of several films. You'll notice that films with names beginning 103a- are much more sensitive to dim objects during long exposures than films like Tri-X. The curve for 2475 Recording Film shows that this film simply stops recording after a while. The advantage of the 103a- films is clear and dramatically illustrated in the matched comparison shots of M-101 on page 47.

Among the conventional films, Tri-X does a fairly respectable job in exposures of 5 to 10 minutes. Bright objects such as the Great Nebula in Orion (M-42), the central part of the Lagoon nebula (M-8), and many bright globular clusters like M-13 can be photographed fairly well with "pushed" Tri-X. All galaxies and most other nebulae, however, require 103a- films for excellent photographs.

Long exposure sensitivity is the most important film requirement for deep sky work, but there are other points to consider. One of these is grain size — all the 103a- films are grainy compared to Tri-X. Objects such as comets and small planetary nebulae have delicate structure, easily lost on grainy film. If your subject is relatively bright, it can be a mistake to automatically use the coarse grained 103a- films. The gossamer tail of a bright comet or the enlarged image of the Ring nebula might be more beautifully recorded on fine grained Tri-X. However, for many faint objects, the incredible recording power of spectroscopic films more than compensates for the extra grain that appears in the final print.

A third major consideration in selecting a deep sky film is its *spectral sensitivity*. Films vary in their sensitivity to different colors of light. All the common films like Tri-X are called *panchromatic*, meaning that they are sensitive to a fairly broad range of colors much like the human eye. But why should the astrophotographer who uses *black and white film* care about *color* sensitivity? The reason is that deep sky objects are often vividly colored — a fact that can help you if you choose the right film. Using a blue-sensitive film with a red object would be pointless. On the other hand, the red sensitivity of some spectroscopic films is a help to city dwelling astrophotographers; use of a red filter to suppress the blue-green skyglow can yield better results. To take advantage of the spectral sensitivity of different films, you must first become "color conscious".

The most highly colored objects are emission nebulae such as the Lagoon and Trifid. This type of nebula is overwhelmingly red due to the natural 6563 angstrom wavelength radiated by the excited clouds of hydrogen gas that make up the nebula. A second type of nebula shines primarily by reflected rather than self-generated light. Reflection nebulae such as that enveloping the Pleiades are very blue objects. Planetary nebulae fall right in the middle of the spectrum; they shine mostly by the green light of doubly-ionized oxygen at 5007 angstroms. Objects composed of large numbers of stars, such as globular clusters and galaxies, emit light over a broad spectrum; these objects tend to be neutral or white in appearance.

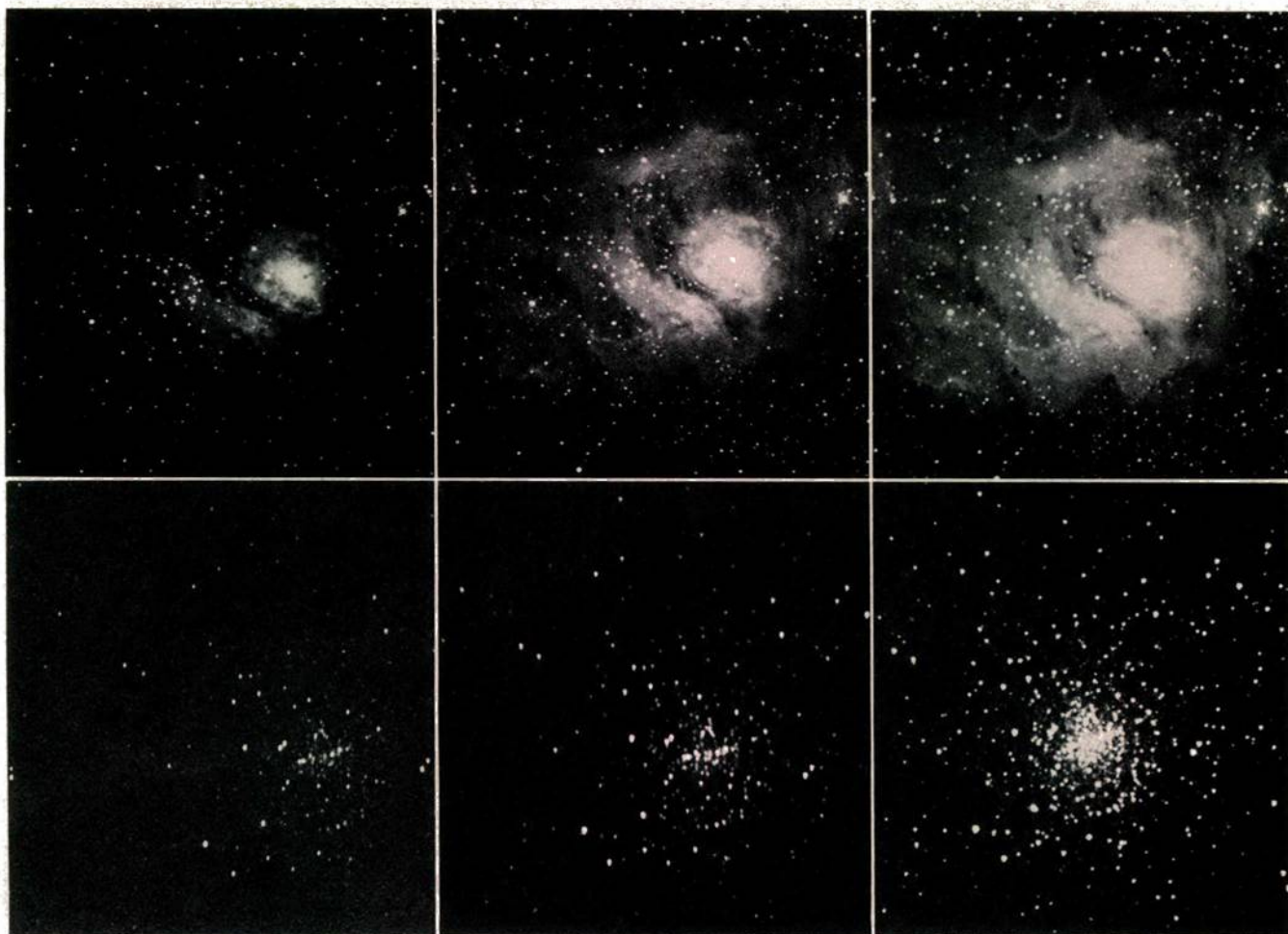
For telescopes with focal ratios of f/4 and higher, the film choices for deep sky work are actually limited to Tri-X or one of the 103a- spectroscopic films. Tri-X works reasonably well on bright globulars and some planetary nebulae, but its poor sensitivity means it isn't good for most red nebulae. Red-sensitive 103aE and 103aF are much more effective on these nebulae, while the blue-sensitive 103aO is good for blue reflection nebulae and dim planetaries.

For the beginner who wants to stick to a single spectroscopic film, 103aE is the best general purpose deep sky film. Although best known for its red sensitivity, it is also extremely sensitive over a broad range of the spectrum, including the blue. 103aO is blue and ultraviolet sensitive *only*, and cannot be used at all for red objects unless they emit blue and ultraviolet light — which most of them do.

Lunar and Planetary Photography

Film requirements for lunar and planetary photography are considerably different than those for deep sky work. Exposures are measured in seconds rather than minutes, so reciprocity failure is no problem. The film characteristics of most concern are grain, contrast and resolution.

The moon is an easy target for conventional



Exposure and film choice profoundly affect your results. The upper row, taken with a 12 inch f/4.5 reflector, are all on 103aE; exposures are two minutes, five minutes, and 10 minutes. Lower row shows film choice for the globular M-4; left to right, 2475 Recording Film, Tri-X, and 103aE. Type 103aE is obviously superior in its ability to record faint stars. Photographs by Greg Griffith.

films. Since it is large and bright, extreme magnifications and high film speeds are rarely of major importance. In close-up photography of the lunar terminator, the deep shadows detailing craters, mountains and rills create a high contrast situation. These contrast levels are easily handled by common films like H & W VTE, Panatomic-X and Plus-X. All these films have lots of "latitude" — that is, they can record a wide tonal range — and they all have fine grain and high resolution. In addition, the relatively high speed of Plus-X (ASA 125) makes it suitable for the dimmer lunar images you get in extreme close-ups at long focal lengths.

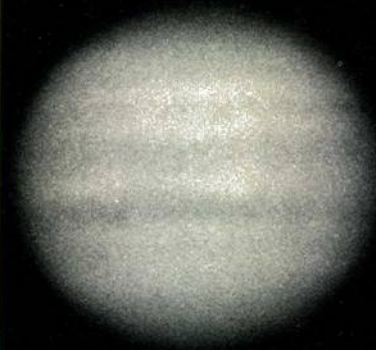
If you want to photograph the entire moon — whether full or crescent — the contrast of conventional films like Panatomic-X and H & W VTE may not be high enough to dramatize the variations in the dark maria, or to highlight the more subtle ray systems around many craters. A better film is Kodak's High Contrast Copy film; it is "contrasty", but also has grain so fine that it defies detection. In order to limit the extreme contrast of this film, many

photographers process it in H & W Control Developer instead of the high contrast D-19, as Kodak recommends. High Contrast Copy is a very slow film that requires some experimentation to find proper exposures; you might rate it at ASA 16 for trial shots. You'll find the lunar disk still requires an exposure of less than a second at the objective focus of any telescope — even an f/15 refractor.

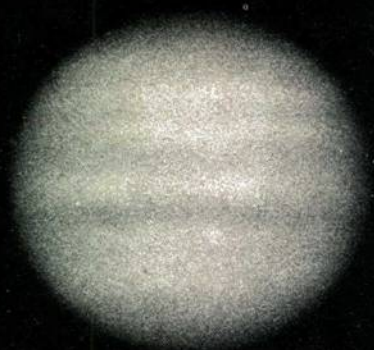
Planetary photography is much more demanding. You need an emulsion fast enough to keep exposures short, thereby minimizing the blurring effects of atmospheric turbulence and drive inaccuracies. But you also need a fine grained and high contrast film to record the maximum amount of low contrast planetary detail. Unfortunately, this idealized high speed, fine grained, high contrast film simply doesn't exist. There may be no perfect solution to this dilemma, but a careful compromise between film speed and focal length can yield excellent results.

Seeing conditions will often determine your choice of films. When planetary images are sharp but undergoing the slow, small modulations that accompany very good (but not excellent) seeing, you may want to use a moderately fast film like Tri-X or Plus-X, a large image scale, and very short exposures to minimize blurring effects. Under ideal seeing conditions, fine grained but slower films are

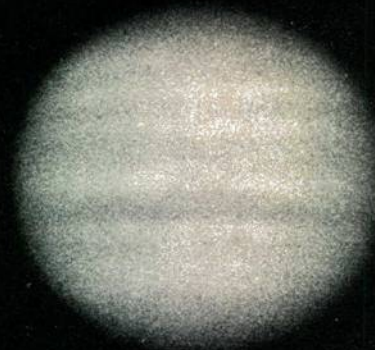
PANATOMIC-X



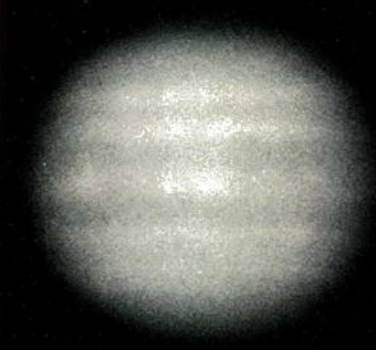
PLUS-X



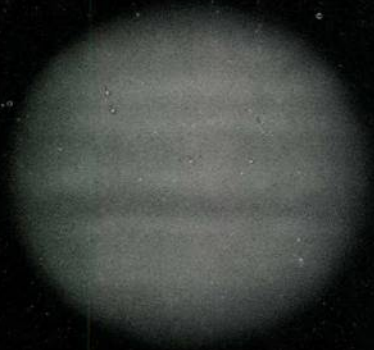
TRI-X



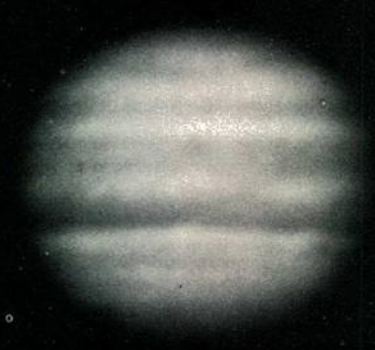
SO-410



H&W VTE



HIGH CONTRAST COPY



at their best. You can compromise a little by using a shorter focal length to produce smaller, brighter images without getting into excessive exposure times. But don't use images so small that sharp focusing becomes difficult, or you can easily lose all the advantages of the fine grained films.

Planetary photography is effectively limited to Venus, Mars, Jupiter and Saturn. Over the years, diligent astrophotographers have successfully used many films to photograph these planets. As a result, if you say that one film is good and another is bad, you'll hear heated shouts of protest from one group or another. But, you may still find the following notes helpful.

Venus is the easiest planet to capture on film because it is extremely bright. Unfortunately, it has practically no photographic markings, so you're stuck with capturing the phase changes that this planet appears to undergo — from small disk to enormous crescent. You can use almost any film, but very fine grained films with wide latitude — such as H & W VTE and Panatomic-X — generally work best, using long focal ratios.

Mars is a difficult but popular photographic subject. It is a small planet, near enough to photograph only during a few months every two years around its opposition date. Even then its disk is never more than about half the size of Jupiter's.

For planetary photography, each of these films has its own special advantages and disadvantages. All were taken with a 10 inch Newtonian using eyepiece projection to give a focal length of 600 inches (f/60). Exposure times were, left to right, top row: one second, 1/2 second, 1/8 second; bottom row: one second, two seconds, two seconds. Photographs by David Hudgins.

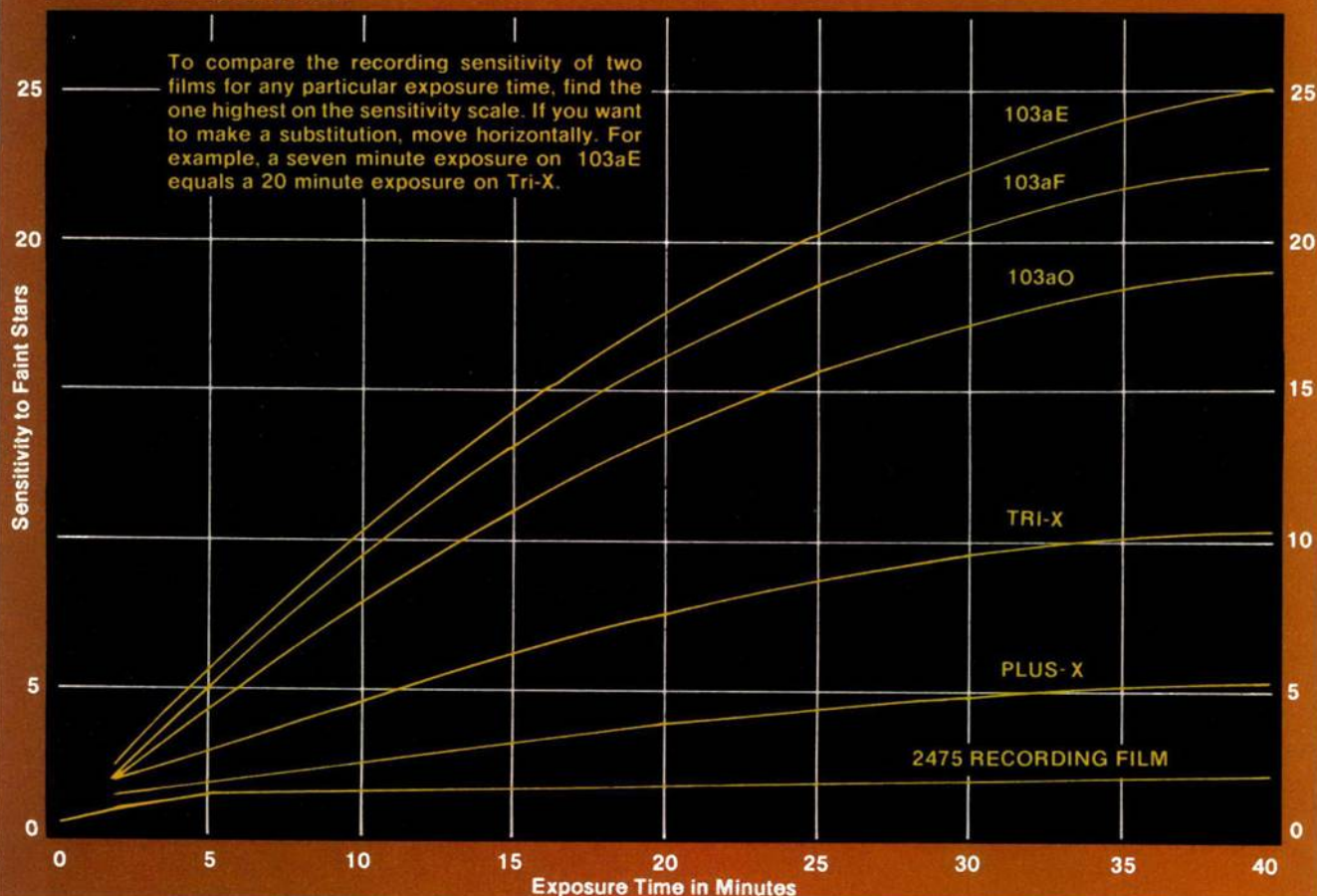
The surface markings on Mars are numerous and of great interest, but also of very low contrast. Under ideal conditions, when exposures of up to 10 seconds are possible, a slow but extremely high contrast film such as High Contrast Copy can give dramatic results. Another high contrast but faster fine-grained film is Kodak's SO-410; this film also has an extended red sensitivity especially suitable for use on the red planet. Shorter exposures are possible with moderately fast films like H & W VTE and Plus-X, and these films can give good results when used with a red or orange filter to increase contrast.

Jupiter is a perfect subject if you're a beginning astrophotographer. It is large, bright, and has enormously detailed structure in its cloud belts. Again, High Contrast Copy and SO-410 will highlight these features. As with Mars, moderate speed, conventional films work well on Jupiter — particularly in combination with a blue filter. To photograph the four bright satellites, use a fast film like Tri-X; your exposure time should be 8 to 10 times that needed to record the planet.

Summary Data on Black and White Astrofilms

Film	CHARACTERISTICS					APPLICATIONS	
	Grain	Contrast	Color Sensitivity	Resolution	Speed (E.I.)	Typical Objects	Most Useful Exposure Range
2475 (forced developed)	very coarse	moderate	pan with extended red	very low	3200	Constellations and meteors (generally using a fixed camera)	0 to 1 min.
Tri-X (forced developed)	moderate	high	pan	moderate	1200	Constellations, comets, bright nebula, globular clusters	0 to 10 min.
Tri-X	moderate	moderate	pan	moderate	400	Saturn, lunar close-ups	0 to 10 min.
103aO	coarse	moderately high	blue only	low	400	Reflection nebula, galaxies, globular clusters, planetary nebula	5 to 60 min.
103aF	coarse	moderately high	pan with extended red	low	400	Emission nebula, galaxies, globular clusters, planetary nebula	5 to 60 min.
103aE	coarse	moderately high	pan with extended red	low	640	Emission nebula, galaxies, globular clusters, planetary nebula	5 to 60 min.
Plus-X	moderately fine	moderate	pan	moderately high	125	Saturn, lunar close-ups	0 to 10 sec.
Pana-tomic-X	fine	moderate	pan	high	32	First and third quarter whole moon	0 to 10 sec.
SO-410	very fine	very high	pan with extended red	high	160	Mars, Jupiter, Saturn, sun, general lunar	0 to 10 sec.
H&W VTE	very fine	moderate	pan	high	64	Venus, Saturn, general lunar, deep sky with Schmidt cameras	0 to 10 sec.
High Contrast Copy	extremely fine	extremely high	pan	extremely high	32	Mars, Jupiter, sun, full moon	0 to 10 sec.

Note that the classifications given for grain, contrast, and resolution are *not* the same as Kodak's, but are comparisons applicable to astrophotography.





Saturn is fairly difficult to photograph. It's quite large, but much dimmer than the other bright planets because it's so far from the sun. Films like Panatomic-X and High Contrast Copy are too slow for reasonable exposures. Through the years, Plus-X and Tri-X have probably been the most common films used on the ringed planet. The new SO-410, with its moderately high speed, fine grain, and good contrast, seems to be the finest film generally available for work on Saturn.

Bear in mind that although rough guidelines are possible, successful planetary photography — more than any other type of astrophotography — relies heavily on experience and on-the-spot judgment.

With one exception, each of the films mentioned is useful within only a rather limited set of applications — a specialization brought about by the incredible ranges of brightness, size and contrast of astronomical objects. The single exception is the very versatile Tri-X. Although Tri-X is rarely the "best" film for any particular application, it's an excellent second choice for a great variety of uses. When processed in a fine grain developer like Microdol-X, it's good for many types of lunar and planetary photography. By switching to a powerful developer like Acufine or D-19, Tri-X becomes a very fast film suitable for constellation and meteor photography, and even a limited amount of deep sky work.

Strongly colored astronomical objects require films with suitable color sensitivity to record them well. Right: The reflection nebula around the stars of the Pleiades is strongly blue colored and can be photographed well on Kodak 103aO film. Photograph by Pat Michaud. At left, hydrogen gas clouds in space, such as the Rosette nebula, glow mainly in the red light of H-alpha, well suited to Kodak 103aE and 103aF spectroscopic films. Photograph by John Sanford.

Tri-X is thus an excellent film to begin with. A little experience with this film will provide a solid base for comparison, and you can move up to more specialized films later on.

To use any film most effectively, you *must* keep brief but careful records of each night's shooting. Include the date, equipment, subject, observing conditions, exposure time, darkroom processing and results. A notebook used for this rapidly becomes a gold mine of information. Refer to it often, and you can avoid repeating many of the same mistakes. Such a record will let you zero in on the films and techniques that give you the most striking pictures — always, of course, the ultimate goal of any astrophotographer. 🐸

David Hudgins is an industrial engineer by profession; at night he pursues his astrophotography avocation in his own observatory in Kansas City, Mo. Greg Griffith, an analytical chemist, has been interested in astronomy for 10 years and in astrophotography for the last four.

ASTRO-NEWS

Latest News From the World of Astronomy

New Evidence Obtained For Discarded Solar Theory

Hot on the heels of recent announcements that the sun behaves very much like a variable star comes the pronouncement that the sun has undergone a number of significant changes in energy output and magnetic activity in the last millennium.

The idea of solar variability, a revival of the discarded 19th century theory that the 11 year sunspot cycle (known as the solar cycle) and the sun itself have changed in recorded time, has profound implications on

solar physics, stellar evolution and possibly Earth's climate.

John A. Eddy, the astronomer who resurrected the theory, made a persuasive case for his hypothesis by comparing numerous sunspot and solar corona observational records dating from the sixth century. He cross-checked his findings with data on the amount of carbon 14 in tree rings, auroral frequency since the 17th century, and fluctuations in terrestrial

surface temperatures in the last several hundred years.

Eddy believes the irregular fluctuations in solar output may be caused by variations in the total radiation output of the sun, presently — though ironically — referred to as the *solar constant*. Variations in solar output were once considered highly unlikely; theoreticians now hotly debate the issue.

The astronomer presented evidence at the annual meeting of the American

Theory continued on page 56

Supernova Predicted In Next 50 Years

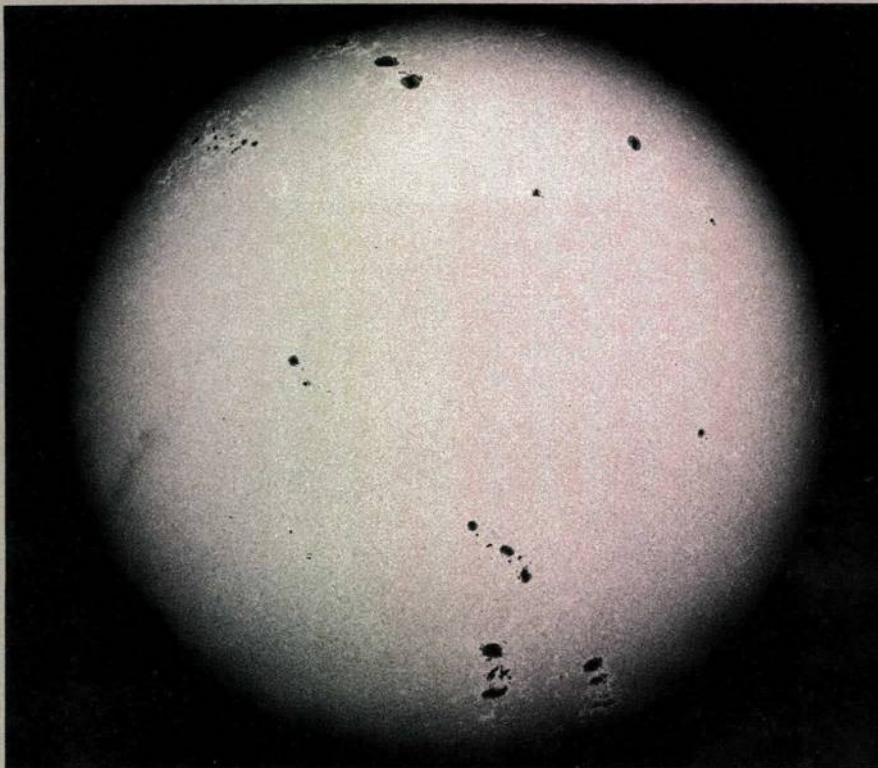
A University of Toronto astronomer predicted that a supernova in the Milky Way will be seen sometime during the next 50 years.

Dr. Sidney van den Bergh has suggested that light from nearly 50 galactic supernovae is racing toward us, and evidence of at least one should be observed in the next five decades. He recommended that astronomers be prepared to observe a Milky Way supernova when it occurs.

Current estimates of supernovae frequency in a galaxy range from three every 1,000 years, to once a century. Only three visual Milky Way supernovae have been recorded in the past 2,000 years: the Guest Nova of 1054 (observed by Japanese and Chinese astronomers but ignored by medieval Europeans); the 1572 Tycho's Nova, and Kepler's Star in 1604. An obscure note by a long-forgotten Egyptian astrologer suggests a supernova was seen in 1006, but it has achieved no consensus among astronomers.

The next galactic supernova, Van

Supernova continued on page 54



Has the sun always behaved as it does now? Using such seemingly unrelated data as climatic variations on Earth, fluctuations in sunspot and aurorae sightings and differing amounts of carbon 14 in tree rings, an American astronomer doesn't believe it has. His findings are stirring up a storm among solar physicists and theoreticians. Photograph by Mount Wilson and Palomar Observatories.

Comets Yield New Information On Composition

Recent observations by space probes and satellites have yielded new information on the chemical composition of comets. Data from several of the comets observed the last two to three years (including Kohoutek) has broadened our knowledge of the molecular and atomic make-up of these strange members of our solar system.

Unlike meteorites, which can be examined when they fall to Earth, comets have been difficult to study. Until recently, little was known about them because they are not usually visible in telescopes until well on their way toward the sun. Only when the sun's radiation and wind dislodges and excites material in the comet's nucleus do we see the bright, fuzzy coma surrounding (and obscuring) the nucleus, as well as the tail trailing behind.

Astronomers could only study the coma and make inferences about the nucleus' components that gave rise to the coma.

Space probes have recently been used to observe comets from above the atmospheric mantle. The probes, and ground based radio telescopes, have confirmed the presence of many molecules and radicals in cometary comae — containing carbon, hydrogen, nitrogen and oxygen.

These fragments, called *daughter molecules* by astronomers, form from the breakup due to the sun's radiation (photodissociation) of the molecules in the nucleus. The fragments lead us to predict what the *parent molecules* might be, though it is sometimes confusing which is parent and which is daughter since some of the molecules recombine as fast as they break up.

Possible parent species include ammonia, hydrogen cyanide, formaldehyde, methyl alcohol, formic acid and cyanoacetylene.

Spectra of comet nuclei obtained by ground based instruments have shown the presence of the same metallic elements found in meteorites: iron, nickel, chromium, aluminum, cobalt, sodium, copper, potassium and calcium. ☛

Supernova *continued from page 53*

den Bergh said in the journal *Astrophysics and Space Science*, will probably be extremely red because of the effects of interstellar dust. Because it will be difficult to distinguish from a less spectacular nova, the astronomers recommended that "each newly discovered 'nova' . . . be regarded as a supernova candidate." A slow decline in magnitude and a ruddy color would distinguish it as a supernova.

The exploding star will stay near its maximum luminosity for about a month. Detailed spectroscopic and photometric studies, as well as accurate measurements of variations in

brightness — crucial to theories on stellar evolution — will be carried out. Van den Bergh suggested that astronomers "look for brightness variations on a short time" basis to detect the presence of a pulsar formed by the explosion. The actual expansion of the supernova's gas envelope might be observed by speckle interferometry.

As the supernova begins to fade, a light echo — a bright ring surrounding the star (similar to a sound echo that results from an ordinary explosion in a canyon) — would be visible. Although much fainter than the supernova, the halo may be detectable for hundreds of years. ☛

Polar Reversal in Field Killed Several Species

A reversal in the polarity of Earth's magnetic field 700,000 years ago coupled with a "storm" of solar flares led to the weakening of the atmospheric ozone layer, and allowed excessive amounts of ultraviolet radiation to reach the planet's surface and kill off several species of marine life, according to a group of atmospheric scientists.

The researchers believe their discovery is relevant to current concern over the depletion of the ozone layer by human-generated pollutants.

A scenario leading to the extinction of some life forms was given: Earth's magnetic field reversed, weakening magnetic forces which shield the planet from a good portion of solar and cosmic radiation. A heavy barrage of solar radiation, together with massive solar flares, allowed excessive amounts of nitric oxide to form, leading to the destruction of a portion of the ozone layer. The impaired protective layer permitted strong ultraviolet rays to penetrate to the surface, killing some species of marine, animal and plant life.

The scientists said that present increases in ultraviolet radiation "would inevitably have some effect on simple aquatic micro-organisms. Aside from possible direct effects on higher forms of life, indirect damage is likely."

Controversy and concern over the possibility that supersonic transport plane exhaust, fluorocarbon propellants and nitrogen component emission from agricultural fertilizers are depleting the protective ozone shield is rampant in scientific and lay communities.

Earth's geomagnetic field decays and reverses itself on an irregular basis of a few thousand to several hundred thousand years for unknown reasons. ☛

BRIEFS

● Accurate size determination of white dwarfs has been a major stumbling block to understanding the composition of these old stars. Researchers at Princeton, Yale and the University of Rochester removed that obstruction recently by establishing the diameter of Sirius B, the condensed companion of the "dog star" in Canis Major, at 2,600 miles.

Using ultraviolet spectrum data for this class of star from the satellite Copernicus, the scientists were able to determine the size of Sirius B.

● A Smithsonian Astrophysical Observatory scientist, applying the Heisenberg uncertainty principle to the gravitational collapse process of black holes, has proposed that these dead-ends in stellar evolution pulsate.

Robert C. Gilman suggests that a black hole does not simply collapse to a particular size within its limiting Schwarzschild radius and remain relatively stable. Instead, he theorizes that it pulses back and forth across the Schwarzschild radius and interacts with its environment. The pulse period can range from 3.6 milliseconds to almost 10 days, depending upon the hole's mass.

● Sunspots are no longer believed to be reliable tracers of the sun's surface rotation. A Sacramento Peak Observatory astronomer, Jacques Beckers, took spectroscopic measurements of the sun's Doppler displacements and compared them to observed proper motion velocities of sunspots at different solar latitudes. He found a large difference between the two rotational rates — the plasma rotation velocity is about four percent slower than the sunspot rate — and concluded that sunspots "are poor tracers for measuring solar surface motions."

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Method to Detect Gravity Waves Proposed

Two physicists have posited a new method for detecting gravitational waves — those elusive phenomena whose existence, predicted by Einstein, has not been established. The technique, if successful, could yield information on the inner workings of black holes, quasars and galaxies.

The proposed method, recently reported in the *Astrophysical Journal*

will utilize radio communication systems used to track interplanetary spacecraft. A network of signals between Earth and these craft would be established, and extremely precise clocks, now being developed, would measure changes in the frequency of the signals due to redshift effects.

The two scientists, Dr. Kip Thorne of Caltech and Vladimir Braginsky of

Moscow State University, believe the detection of gravity waves would lead to our understanding of what happens deep in the nuclei of stars, star clusters and galaxies, in addition to quasars, pulsars and black holes.

"Once you've found (gravitational waves)," Thorne said, "you can use them as you use the light from stars to tell what's going on in the universe. The disadvantage of light is that it reveals only the surfaces of objects. Because gravitational waves come from the interiors of objects, they can be very powerful tools in revealing cosmic activity...never seen before."

The length of the waves would indicate the event's size: The longer the wavelength, the larger the event. Explosions in galactic and quasar nuclei would produce gravity waves with a wavelength of 6,000,000 miles.

The discovery of these waves rests on the development of an extremely accurate clock. Now being developed at Stanford University is a superconducting cavity oscillator, which will surpass the sensitivity of the hydrogen-maser clock, currently used in space tracking. Because the required clock is still in the developmental stage, Thorne and Braginsky expect the search for gravity waves may not succeed for 5 to 10 years.

The collision of two giant black holes deep in the core of a galaxy would produce the desired "large" gravitational waves. An uncertainty facing the search is the occurrence frequency of such large scale phenomena. If such events take place as often as once a week, Braginsky and Thorne believe they can be detected. However, if the period is as infrequent as 300 years, Thorne said gravitational wave astronomy at long wavelengths is a hopeless enterprise. But if long waves are detected, Thorne said "it will have a tremendous payoff in terms of learning about violence on a large scale in the universe."

In 1969, University of Maryland physicist Dr. Joseph Weber reported the discovery of gravitational waves from "small" events. Other scientists failed to duplicate the data, and Weber now doubts he detected them.

Gravity is the weakest of the four types of force in the universe. The others, in descending order of magnitude, are strong atomic, electromagnetic and weak atomic forces. Some scientists dispute the accepted hierarchy of force, suggesting that electromagnetic and gravitational forces are linked in some unknown fashion.

Two More Blows Strike Shaky Steady State Theory

With its credibility losing ground every day, the steady state cosmological theory is reeling from the delivery of two near-fatal blows from different astronomical quarters.

The first, landed by radio astronomer Adrian Webster of Cambridge University, places the positions of quasars and radio galaxies firmly at cosmological distances. Four Tufts University researchers threw the second with their findings that galaxies, radio galaxies and quasars are dispersed isotropically throughout the universe and are linked in an evolutionary sequence.

Webster employed a new statistical technique — power spectrum analysis — which used five different celestial catalogs and a computer to compare data. His technique gave no evidence for grouping or clustering of the examined sources. Webster said this settles the question of quasar distances; if quasars were not at cosmological distances, as has been suggested, they should be grouped in clusters in the same way that local galaxies are. Webster's data rules this out.

A minority school of astronomers ascribe the observed luminosity of quasars not to cosmological distances of thousands of megaparsecs but to "neighborhood" distances of less than 100 megaparsecs (a megaparsec is 3,260,000 light-years). Photographs of quasars in the line of sight of nearby galaxies are interpreted as showing quasars recently ejected from these galaxies. Webster's results reject this interpretation; the photographs apparently show mere chance coincidence.

Webster's work, presented to the Royal Astronomical Society, also boosts the standard belief that matter is distributed rather evenly throughout the universe. Averaged over a large enough area (150 megaparsecs or more), the density of matter varies by no more than 10 percent.

The Tufts University researchers — using a new Hubble diagram compiled from 1,100 galaxies, quasars and radio galaxies that were sampled — found an evolutionary sequence linking the three classes of objects. The different species generally do not intermix in either magnitude or redshift. Quasars, radio galaxies and normal bright galaxies have mean luminosities, respectively, of 10^{44} , 10^{45} and 10^{46} ergs per second, while their respective speeds of recession decrease geometrically. As the luminosity increases, so does the "look-back" time (the difference in time between the generation of the light and when it is observed on Earth).

Adding weight to the researchers' conclusions was the finding that quasars are dispersed over a magnitude range comparable to that of galaxies.

Stellar theoretician J. V. Narlikar once said that a typical Hubble diagram for quasars "looks like a scatter diagram, and only an eye of faith might spot a smooth curve running through the points. . . one is led to suspect that because the quasars do not seem to follow the Hubble law, their redshift may not be due entirely to the expansion of the universe." However the research team parries, "If one supposes that the Hubble diagram for (quasars) does not suggest that they take part in the expansion of the universe, then we must draw the same conclusion about the brightest normal galaxies."

The Tufts group's results do not indicate whether the universe is still expanding or decelerating, lending no fuel to current cosmological disagreements over an open universe.

Hubble's law, formulated in 1929, established that recession speeds (redshift) of other galaxies correlated with the objects' apparent luminosity, which depends on distance. It assumed that the redshift is caused by a Doppler effect in an expanding universe.

Theory *continued from page 53*

Association for the Advancement of Science in Boston last February of three periods when solar activity was at low ebb: the years 1100 to 1250, 1460 to 1550, and 1645 to 1715 — a pronounced 70 year period when sunspots were virtually absent from the sun's disk. The total number of sunspots reported in that 70 year span was less than the number that normally are seen in a single year near solar maximum.

Critics have suggested that Eddy's findings are based on incomplete or false data, a charge leveled at two 19th century astronomers who first proposed the idea of solar variability. Gustav Sporer and E. W. Maunder drew attention to the virtual absence of sunspots during 1645 to 1715, but their evidence rested heavily on the absence of historical evidence for sunspots during these years.

Eddy said there is new evidence that supports his contention. "We now have better catalogs of historical aurorae, compilations of Oriental sunspot observations, a fuller understanding of tree ring records, and a new tool in atmospheric isotopes as tracers of past solar activity."

The lack of sunspots seen during 1645 to 1715 cannot be ascribed to a lack of astronomical equipment. Techniques used to observe these regions of intense magnetic activity are similar to those in use today. Further, interest in sunspot phenomena was high; spotting one was reason enough for publishing a scientific paper.

Auroral activity is one check on solar activity. There is a strong correlation between sunspot activity and aurorae, since aurorae are produced by the collision of charged solar particles with molecules in Earth's upper atmospheric regions. Sightings were rare in the 17th century; during the period from 1640 to 1700, only 77 aurora were seen. Normally, there should have been 300 to 1,000 nights of auroral activity in Europe during that time. During one 37 year segment of sunspot minimum, no aurorae were seen anywhere. From 1716 on, sunspot activity reached normal levels and aurorae returned to the night skies.

Oriental records, relying on naked eye sightings, recorded no sunspots or aurorae between 1639 and 1720. Though the record is fragmented, Eddy said the "Far East gap . . . matches Western Hemisphere data very well." Sunspots were important to Japanese, Chinese and Korean mythology and legend, and historical records noting sunspot sightings go as far back as 28 B.C.

The Oriental records also show sunspot inactivity from 1520 to 1604, and

from 579 to 808. They reveal an intensification of sunspot and aurorae sightings in the 200 year period centered around 1180, halfway between intense solar activity in the seventh and early eighth centuries, and inactivity in the latter half of the 17th century.

A surprising confirmation of solar activity can be found in the largest plants on Earth: trees. All living things absorb carbon 14, produced by cosmic rays acting on carbon dioxide molecules in Earth's atmosphere. When an organism dies, it no longer absorbs carbon 14; the amount present in the body begins to decay at an established rate. However, the production of carbon 14 varies according to solar activity. The amount of carbon 14 produced in the atmosphere increases when solar activity is low, while an increase in solar magnetic phenomena blocks out some of the cosmic rays reaching the atmosphere and results in a decreased amount of carbon 14 absorbed by organisms during that time.

Studies of tree rings have demonstrated that there was a 20 percent increase over the average abundance of carbon 14 during the years 1640 to 1720, which agrees favorably with sunspot and aurorae inactivity during that time. Carbon 14 records in tree rings also indicate an earlier period of solar inactivity from about 1460 to 1550 and a peak of activity from about 1100 to 1250. Eddy plotted the relative deviation of carbon 14 as well as the number of annual sunspots and naked eye Oriental sunspot sightings, and said that the carbon 14 record "does a pretty good job of matching the cycle". He stated it stronger in his accompanying paper: "The three quantities give a wholly consistent representation of the (70 year) minimum."

Another indicator of solar activity is the corona observed during a solar eclipse. In periods of high solar activity, coronas appear more dramatic since they are accompanied by huge streamers associated with intense magnetic fields on the sun's surface. Eddy examined records of solar eclipses

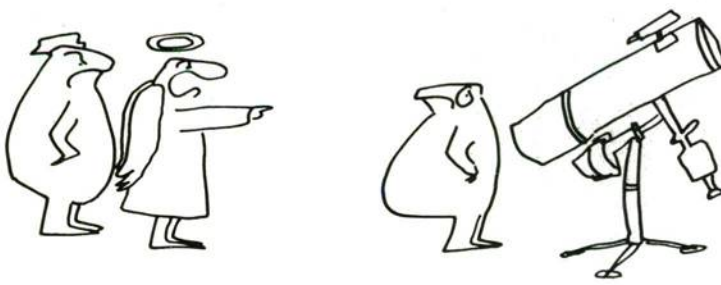
in 1715, 1706, 1698 and 1652; no description of streamers was noted for the last three sightings, and the corona of each lacked any structure of appreciable size. The corona associated with the 1715 eclipse was described in familiar, modern terms; sunspot activity was rising as the sun was climbing out of a 70 year snooze.

Most concern about the sun's fluctuating output concerns its effect on Earth's climate. Eddy noted, as have other investigators in the last 15 years, that the 1645 to 1715 period of solar inactivity corresponds very closely with the coldest point in the mini-ice age Earth experienced in the 17th century (now referred to as the Little Ice Age). The solar activity minimum in the 16th century coincided with the other temperature minimum of the Little Ice Age. "The climate curve," Eddy observed, "looks a lot like the curve of variability in solar activity."

The sun has behaved in the last 200 years, "better than . . . the previous 1,000 years," said Eddy. Unpredictable changes in solar energy output in the near future, however, have scientists worried. A variation of one or two percent would have profound effects on terrestrial climate, although variations in the sun's magnetic activity are not believed to cause any climatic variations.

Solar physicists have not developed an acceptable model of the magnetic mechanism responsible for the 11 year sunspot cycle and variables in solar activity. Suggestions have been made that the mechanism results from the interaction of convection and solar rotation. Long term changes in solar activity might be caused by changes in convective activity.

The idea that solar activity can and has varied over extended periods of time rejects long cherished assumptions about the dependably steady sun. "We've shattered the Principle of Uniformitarianism for the sun," Eddy said. "We've finally broken a block that has held us back. . . . It was an assumption we took as fact." 



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continued on page 63



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Well here it is finally, the memo I promised that will introduce all ASTRONOMY employees to you. So, without further ado, I proudly introduce the staff. Just so you know, the entire staff is very young, spanning a narrow age range of only nine years; the youngest is 23 and the oldest, 32.

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Rosemary Pickart is one of **ASTRONOMY's** most indispensable people — which may seem a little strange since she isn't an editor. But the fact remains that **Rosemary**, who heads up **Subscriber Relations**, is your most important contact at this magazine. Why? Suppose you have been a subscriber since our first issue in August 1973. Your magazine has arrived like clockwork each month, but suddenly for some reason it stops coming. Your first step in solving the case of the missing magazine is to contact **Rosemary**.

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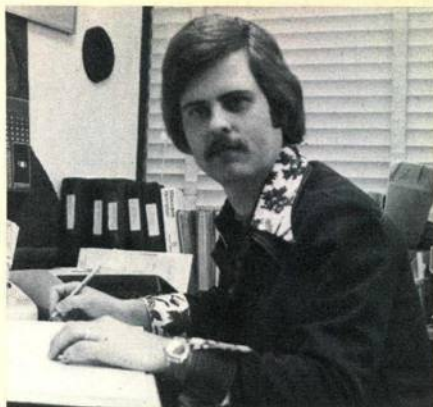
Rosemary is quite versatile, handling other things as well — such as the filling of orders for back issues, calendars, reprints and posters. And, often in spite of the Post Office, she makes sure these items are mailed to you swiftly. Again, any problems arising out of delivery or damaged items are handled by Rosemary.



Nancy Faustmann administrates Bulk Copy Sales. ASTRONOMY is basically a mail subscription magazine but we do sell about 2,000 copies monthly to newsstands, bookstores, museums and planetariums. Nancy makes sure these and new accounts receive their bulk orders on time, and handles general correspondence on bulk sales.

Nancy has to be, without a doubt, the world's greatest copy typist. After all the words in ASTRONOMY have been written, rewritten, edited and otherwise processed by the editors, they must be swiftly and perfectly typewritten. This copy is then sent to the typesetter where it is converted to the clean, even lines and columns of type that appear in the magazine. Every word that appears in ASTRONOMY each month has been typed at least once by Nancy.

The largest portion of her job, however, is secretarial; she is my personal secretary and does an outstanding job. Without her reminders, I probably wouldn't attend any of my appointments — including the doctor.



Peter Trabbold is a fairly recent full time addition to the staff. As our accountant, he is responsible for paying bills promptly and keeping track of the money *ASTRONOMY* receives from subscriptions, advertising and miscellaneous sales. While Pete's duties involve subscribers especially where accounting and circulation fulfillment (that computer again) overlap, his greater responsibility is to AstroMedia Corp., the corporate entity that publishes *ASTRONOMY*.

In this regard he provides the corporation with monthly financial statements, makes growth projections, and helps determine the financial feasibility of our magazine-related products such as reprints, etc.



Stephanie Kiel is an administrative assistant, which in every day lingo means she works in many different areas at the magazine.

She works directly with Pete doing clerical bookkeeping, advertising and miscellaneous billing, etc. She also distributes everyone's mail and, as telephone receptionist, channels phone calls to the right people.

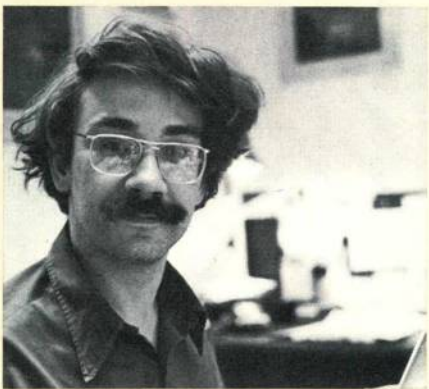
Steff also fills in wherever an extra pair of hands might be necessary — in the editorial department, subscriber relations, aiding the corporate administrators.

A great organizer, she has a real flare for interior decorating which will prove valuable when *ASTRONOMY* moves to new, larger offices in July. Stephanie will then become the magazine's official receptionist.



Katherine King joined *ASTRONOMY* as editorial secretary around the same time that Pete joined the staff. Since mid-October last year, she has helped bring order and sanity to the chaos that previously existed in our editorial department. Acting as librarian, Kathy is responsible for maintaining and updating all files, and is a great help in enforcing departmental procedures. Contributors' manuscripts and photographs are now swiftly logged, acknowledged, accepted/rejected and filed as a result of her organized efficiency.

Kathy is very well suited to her job having worked for several years as a high school English and communications teacher after graduating from the University of Wisconsin-Milwaukee. Additionally, she worked for the Milwaukee based Kalmbach Publishing Co. on *The Model Railroader* magazine as an editorial secretary.



Richard Berry is *ASTRONOMY*'s new technical editor. A graduate of the University of Virginia, he received his master's degree in astronomy from York University in Toronto in 1972. His thesis emphasized photoelectric photometry and included investigations of anomalous post-eclipse brightening of Io. Professionally he has built or worked on ground and rocket based instrumentation for upper atmospheric studies, worked with the IntraSpace International group that provided the ultraviolet light source for the Apollo/

Soyuz experiment, measured air pollution levels using lasers, and designed professional telescopes.

A longstanding council member and then member of the board of directors of the Royal Astronomical Society of Canada, Toronto Centre, he is active in observational astronomy, and designs and builds telescopes, cameras, etc. He is also an accomplished astrophotographer and darkroom technician.

Richard writes and/or edits technical lead features and articles for *Photography in Astronomy*, *Equipment Atlas* and *Gazer's Gazette*. If you have questions about articles that appear in these departments, he's the one to write to.



Henry Phillips, editorial assistant, is the longest tenured of *ASTRONOMY*'s new editors, having joined the staff in December 1975. A graduate of Loyola University of Chicago with a major in English, Henry worked as copy editor for *Encyclopaedia Britannica*, and was both a research and copy editor at *Prism*, a magazine published by the American Medical Association. He has been active in observational astronomy for 10 years with interest that has specialized in starlore and mythology of the total night sky (southern hemisphere as well); binocular and naked eye sky observing; observation of the moon, double stars, variable stars and planets.

His expertise is such that he's primarily responsible for writing *Sky Almanac* and the introductory portion of *Star Dome*. Naturally, this isn't all he does; he also writes or edits the less technical *Gazer's Gazette* and *Equipment Atlas* articles, and edits lead features and *Stellar Frontiers*.

Henry would like to know whether or not you like the skylore section of *Star Dome*, and would appreciate suggestions on how to make it more interesting. In addition, if you want to report your observation of some celestial event, you can send these letters to Henry for possible inclusion in *Sky Almanac*.



Kenneth Engel, also brand new to ASTRONOMY, is a staff associate. While attending the University of Minnesota, he majored in journalism with emphasis on interpretive reporting, newspaper writing and editing. He was head copy editor for *Technolog* magazine and reporter for the *Minneapolis Daily*, both student publications, while in school. He worked for the *Minneapolis Tribune* and was a reporter/editor before joining ASTRONOMY. Ken has been an astronomy enthusiast for 17 years with primary interest in observational astronomy.

While Ken performs a variety of duties in the editorial department, his education and experience make him well suited to handling Astro-News, his primary responsibility. In the next few months you should start seeing changes as Ken develops and upgrades that department. Naturally, he's eager to hear from you and welcomes your suggestions.



David Schwartz, production manager, has been with ASTRONOMY since October 1973. Besides occasionally sending us all into fits of laughter with his quick wit and imitations, he's responsible for physically "puzzling together" the hundreds of bits and pieces that comprise the final magazine you open and read each month. For example, he makes sure that all pages fall in proper sequence, and that the beginning of one article or department doesn't end up in the middle of another.

The real tribute Dave deserves,

however, is for staying awake all night doing final color corrections at press when ASTRONOMY is printed every month. Incredibly, the magazine always seems to go to press sometime in the afternoon or early evening. Dave remains at press overseeing the printing to make sure the color quality remains consistent so we can continue to make the claim that ASTRONOMY is the world's most beautiful astronomy magazine.

Dave is a graduate of Carroll College in Waukesha, Wisc., and is a member of the Society of Publication Designers. An avid photographer in his spare time, he is often asked to judge area art or photography shows.



Penny Oldenburger is ASTRONOMY's longest tenured employee and was the first person hired when the magazine started full time operation in May 1973. While her titles are managing editor and communications officer, her duties have been and are so extremely varied that she can't be considered anything less than my assistant. She has worked in nearly every department as a troubleshooter, analyzing and organizing systems and procedures. As a result, she knows more about the operations of the magazine than anyone else such that, if anything were to happen to me, Penny's leadership would allow the magazine to keep going.

Realizing this fairly early, in November 1974 I made her vice president of AstroMedia Corp.

Her management of the editorial department has kept us on schedule so you receive your magazine on or before the first of each month. She was also responsible for developing the written style we use in the magazine, giving all articles a consistent style. As communications officer, she is responsible for press coverage and other television/radio publicity we've received since we started.

Coupled to (some would say piled on) these duties, she handles the advertising in the magazine and administers ASTRONOMY's policy of consumer advocacy.

Penny is a mass communications graduate of the University of Wisconsin-Milwaukee, and has attended several seminars at New York University's School of Business and Management. She is a member of both the International and Wisconsin Associations of Business Communicators.



And finally, I'm **Stephen Walther**, publisher and editorial director, and president of AstroMedia Corp. I am a communications graduate of the University of Wisconsin-Stevens Point, and was a founding director of the Milwaukee Chamber Music Society (my primary outside interest).

Besides writing bizarre Publisher's Memos, I oversee and direct the editorial content and function of the magazine, and set policy and manage ASTRONOMY's overall business operations. The biggest part of my job, however, is in marketing and business development.

In this regard, I'm the one who develops ASTRONOMY's direct mail and advertising campaigns to increase circulation. Also, I determine whether a new reprint, poster, book, calendar, special issue, etc. is marketable at a given price, and then create the advertising to sell it.

But most important of all, I'm the fellow whose dream was ASTRONOMY magazine — and that dream is now coming true through the dedicated toil of 10 other enthusiastic employees. ASTRONOMY magazine is now their dream too. Together, we work to keep it an unblemished reality in order to continue giving you, the readers, the world's most beautiful astronomy magazine.

We now await our next command. What is it you desire?

Sincerely,

Stephen A. Walther

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ASTRO-MART

continued from page 57

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FOR SALE — Meade 640 focuser, mint condition; best acceptable offer under \$21.00. 8" coated mirror, few scratches, 45" f.l.; best acceptable offer under \$35.00. Original tool included if desired. Write Edward Crenshaw, Rt. 1, Box 50, Waterloo, SC 29384.

FOR SALE — Back issues of ASTRONOMY: September through December 1973, January and August 1974; \$8.00 each. February 1974; \$5.00. April 1975; \$3.00. First money order only. Contact L. Dykes, 1080 Claremont Ct., Tacoma, WA 98466. Phone (206) 564-5863.

FOR SALE — New Bounty Hunter II metal detector. Was \$89.95; will sell for \$35.00 with full 1 year guarantee. Send check or money order to Mark Eckard, 117 Church St., Little Falls, NY 13365.

FOR SALE — Deluxe 10" f/7 Cave Newtonian Astrola reflector with equatorial mount, portable stand, electronic clock drive, electronic slow motion control. One year old. Price: \$700.00. Contact Steven Nicosia, 819 Lane Dr., Apt. #2, Rosenberg, TX 77471. Phone (713) 232-6395.

FOR SALE — Back issues of ASTRONOMY: February, July, August 1975. In top condition. Will sell for \$6.00 each or \$20.00 for all three. Write Christopher Phillips, 110 Lydecker St., Englewood, NJ 07631.

FOR SALE — 7 x 50 Bausch & Lomb Navy binoculars with case; \$55.00. Zoom eyepiece (8.4-21mm); \$25.00 or will trade eyepiece for 115 volt Horst Reversible 1/2 r.p.m. motor. Write David E. Garcia, 1345 Garner Ave., San Bernardino, CA 92411.

FOR SALE — 6" f/7.5 mirror and diagonal; 45" focal length. Excellent condition. Price: \$50.00 plus shipping or highest offer. Write Craig Lindberg, 7355 56th Ave. N.E., Seattle, WA 98115.

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FOR SALE — CM Designs clock drive corrector. Like new; originally cost \$80.00. Will sell for \$25.00 plus postage. Contact Clifford P. Livermore, P.O. Box 843, Kailua-Kona, HI 96740. Phone (808) 329-3220.

FOR SALE — Edmund zoom eyepiece; seldom used. Price: \$20.00. Write Donald A. McKenzie, 717 Apache, Aztec, NM 87410.

FOR SALE — 60mm Empire refractor with 12.5mm and 5mm Ramsdens, diagonal prism, solar filter, equatorial mount, telescoping tripod. Price: \$50.00. Contact Brian Massa, Rt. 7, Box 7148-E, Nampa, ID 83651. Phone (208) 466-4814.

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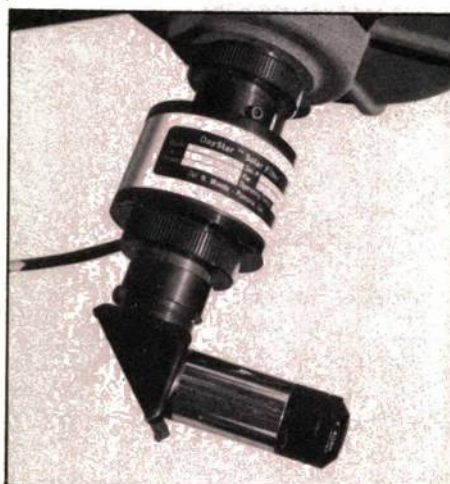
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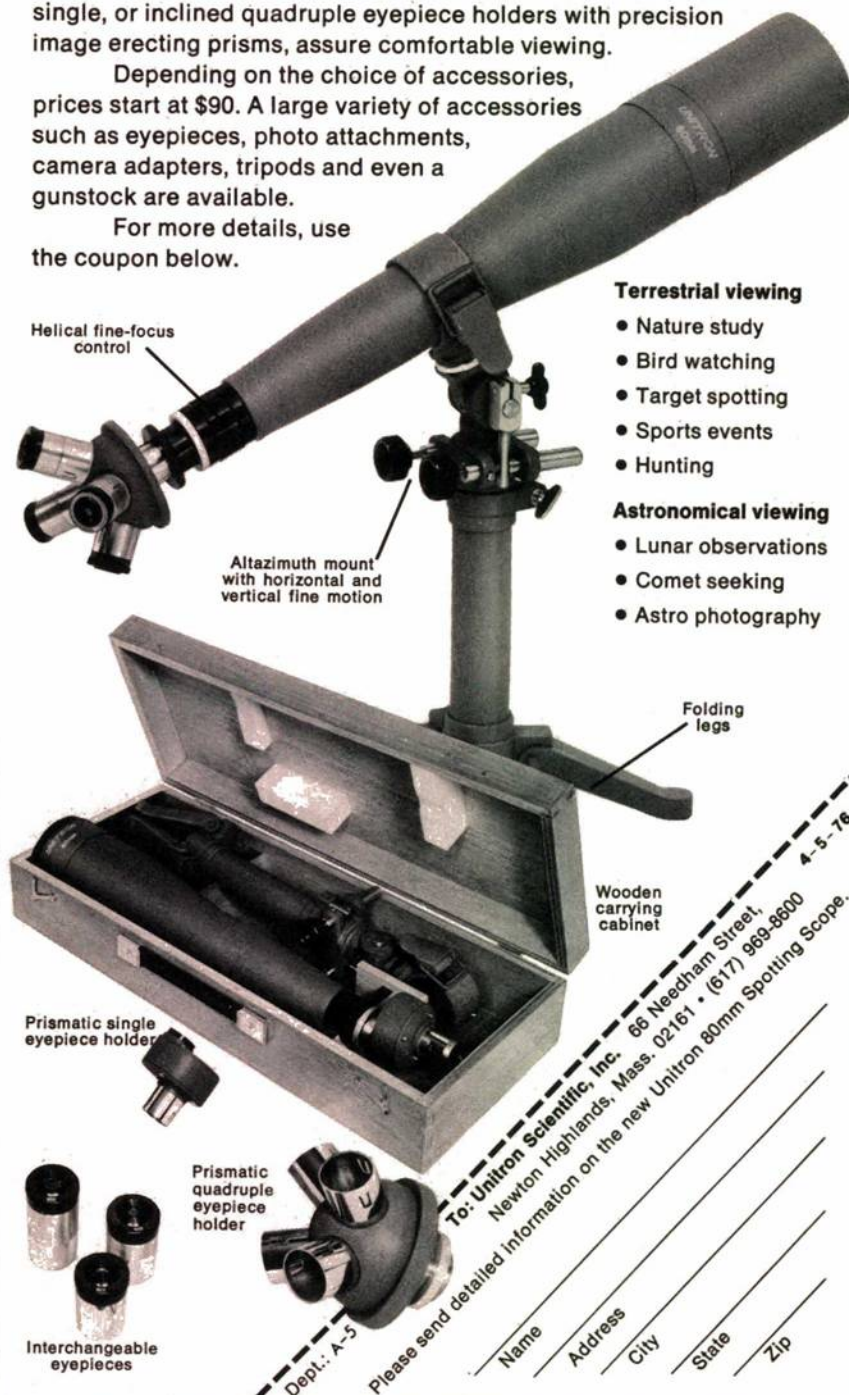
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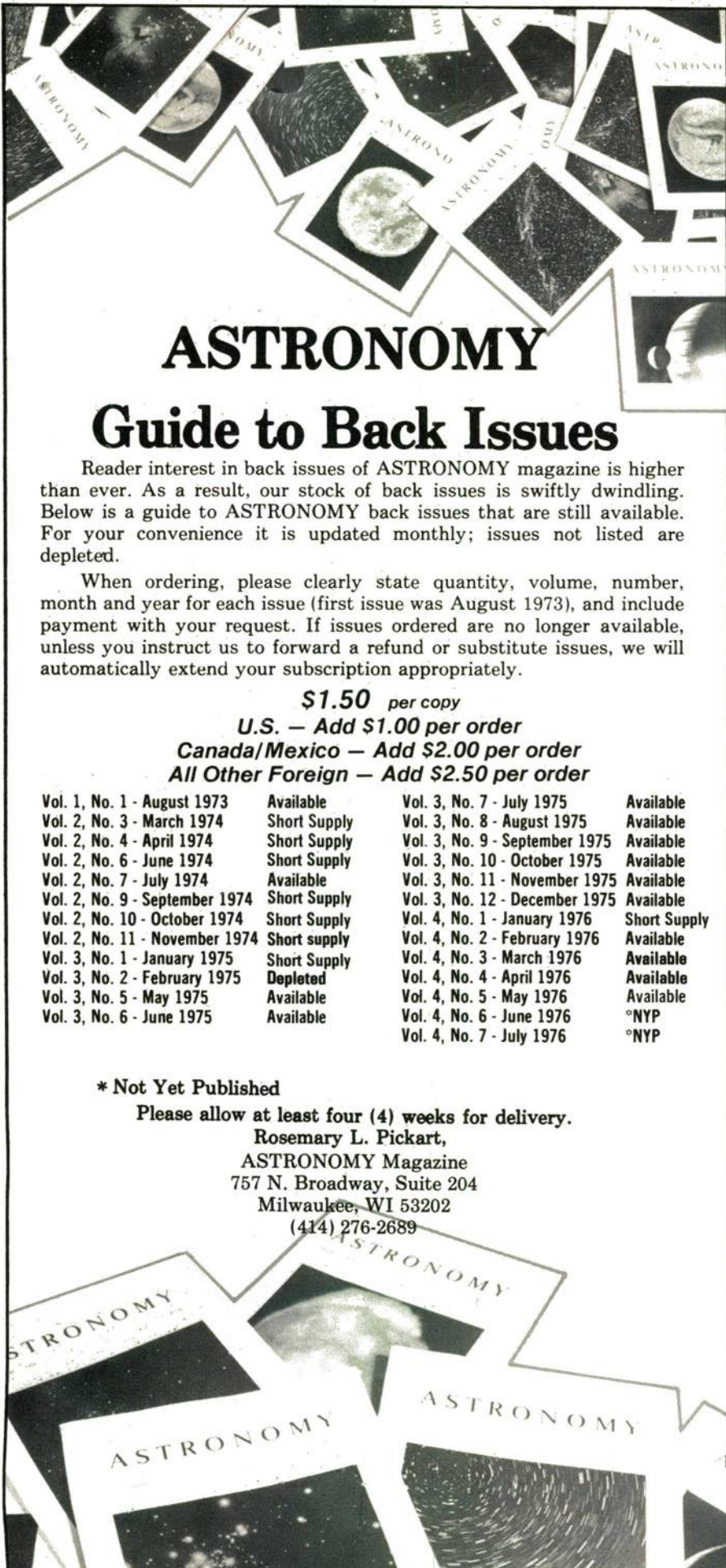
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WANTED — Books, magazines, records, tape recordings on space program (U.S. or USSR). Also slides, photographs, models. Send list to Howard Gluckman, 5400 Newcastle Ave. - #69, Encino, CA 91316. Phone (213) 345-7609 after 6 p.m.

WANTED — Correspondence with persons interested in 6" or larger fixed eyepiece Newtonian RFT (not Springfield type). Am preparing to design a portable one. Write Thomas F. Johnson, 125 Congress Ave., Waterbury, CT 06708.

WANTED — Depleted issues of ASTRONOMY in excellent condition for reasonable price. Also information on Selsi or Assanuma 4-1/2" equatorial reflector. Contact Matthew J. Kuhn, Box 8312, State University of New York at Binghamton, Binghamton, NY 13901. Phone (607) 798-4220.

WANTED — Chesley Bonestell paintings, prints, books, etc. Send details. Write John Mosley, 15 S. State St., Salt Lake City, UT 84111.

WANTED — Correspondence with persons (preferably male, ages 11-14) interested in astronomy, UFOs, intelligent life, Bermuda Triangle. Must be good in math. Write Christopher Rendenna, 83 Sylvan St., Rutherford, NJ 07070.

WANTED — Celestron 5 or 8 in mint condition. Should have adjustable wedge, drive, slow motion control, accessories for astrophotography. Contact John Spellmeyer, 3010 Parkwood Dr., Richmond, IN 47374. Phone (317) 966-4970.

WANTED — Plans for building a drive corrector and voltage inverter (12 volt DC to 110 volt AC). Write Michael E. Thacker, 3115 Woodfield St., Cincinnati, OH 45213.

WANTED — Dynamax 8 or Celestron 8 (will consider 5). Please describe. Contact Carl Tolonen, 321 Callecita Pl., Santa Fe, NM 87501. Phone (505) 388-4891.

WANTED — Used 35mm SLR camera body suitable for astrophotography; must be in good condition. Also plans for construction of clock drive for 8" Newtonian with 1" shaft. Contact Steven Wissler, 15309 Kornblum Ave., Lawndale, CA 90260. Phone (213) 675-7316.

WANTED — SMB-3 declination slow motion control for RV-6 Dynascope; also 5.5" Celestron Schmidt camera. Write Richard Zepernick, 12 Evans Rd., Cresskill, NJ 07626.

WANTED — Back issues of ASTRONOMY: October, November, December 1973; January, February 1974. Advise price and condition. Contact Douglas Zwach, 518 N. State, New Ulm, MN 56073.

INFORMATION WANTED — On where to purchase Burnham's "Celestial Handbook", sections 5-8. Write J.R. Nichols, 804 McKeveit Rd., Santa Paula, CA 93060.

FREE — "The Weather Observer", a bi-monthly newsletter devoted to amateur meteorology. Send SASE to Michael McClure, Rt. 2, Box 198, Princeton, KY 42445.

STAR DOME

MAY

by

James Mullaney and Henry J. Phillips

On May evenings, the Milky Way is stretched all around the horizon, completely invisible from most of the United States. The constellations that reach the zenith this month contain mostly faint stars and inconspicuous patterns. There is nothing for the naked eye observer that can compare with winter's great circle of first magnitude stars, or the summer triangle; we have to be content with the so-called Virgin's Diamond, which is formed by Arcturus, Spica, Denebola, and Cor Caroli (the brightest star in Canes Venatici). Since the latter two stars are not first magnitude, the diamond is not as prominent a configuration as the other seasons' landmarks — but it's the portal to an immense crowd of galaxies known as the Coma-Virgo cluster. When we see the diamond high in the May sky, we can look through it deep into intergalactic space.

Galaxies, however, are a treat for the telescopic observer, and those who have only their eyes to use may be disappointed with the May stars. Large areas of the sky are almost completely blank, or at best contain a few widely scattered stars. In addition, only three first magnitude stars ride high above the horizon, and the casual observer may conclude that May is a poor month for stargazing.

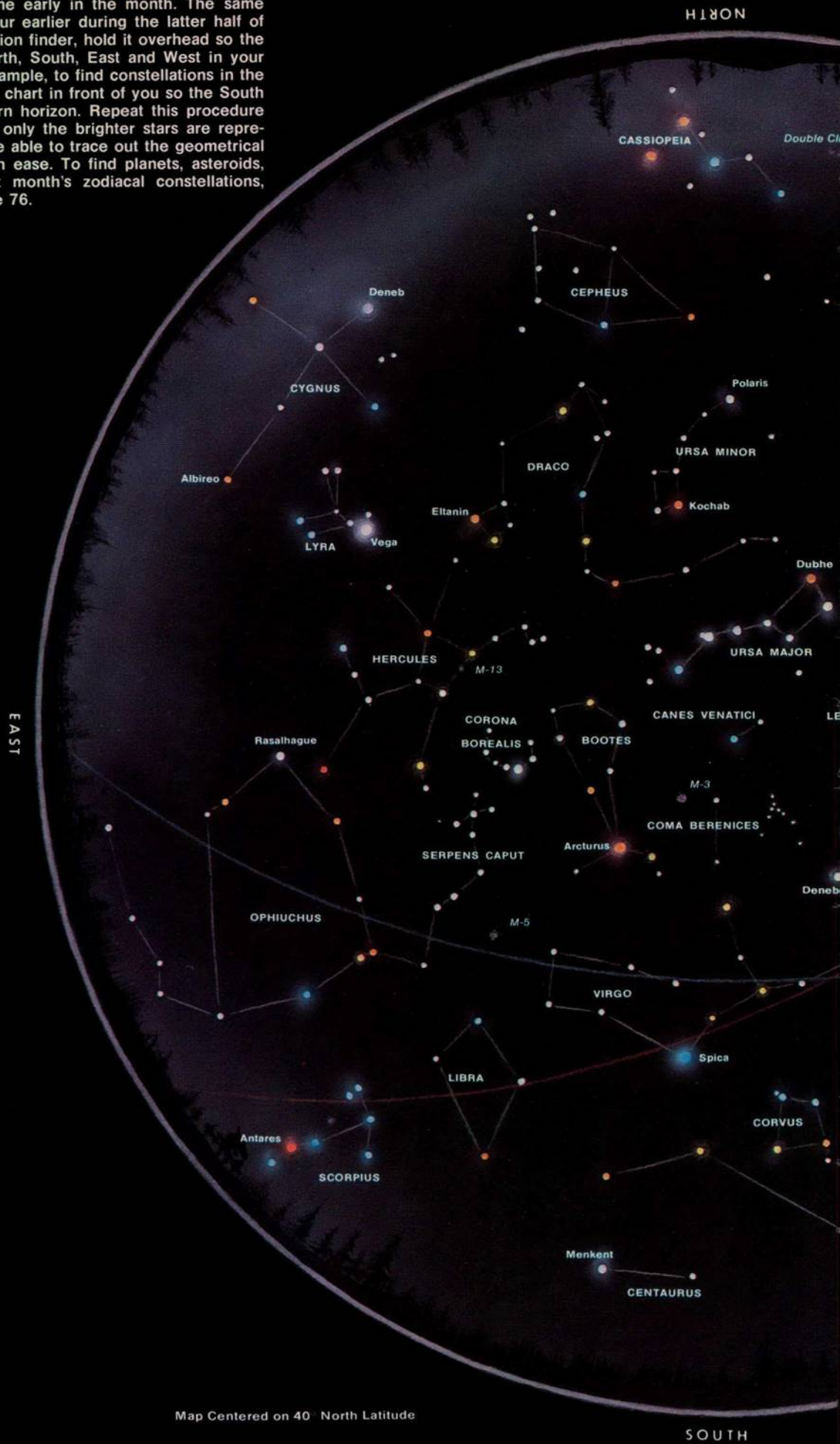
Nevertheless, the May constellations do have their good points. For one thing, many of them are huge. There are nine constellations that have areas greater than 1,000 square degrees, and six of these — Hydra, Virgo, Ursa Major, Hercules, Draco and Centaurus — are easily visible on May nights. It's true that Centaurus rises only partly above the horizon, but the farther south you live, the more of the centaur you can see. In southern Florida, Alpha and Beta Centauri — both first magnitude stars — are low above the southern horizon for most of May. Centaurus contains many other bright stars; second magnitude Menkent (Theta Centauri) is easily visible from higher latitudes, and can be found on our monthly map.

Most of the other May constellations are small and fill up the spaces between the larger groups. Three tiny constellations are balanced upon the back of Hydra. The brightest of these is Corvus the crow, formed by a small quadrangle of second and third magnitude stars located southwest of Spica. It is also known as the Raven in some countries; Corvus' brightest star, Gamma (magnitude 2.3), is named Gienah, from the Arabian right wing of the raven. Corvus has always been a pleasant, fairly innocuous group — except to the Chaldeans, for whom it was one of the monster ravens borne by the dragon Tiamat to aid in her attempt to lay the entire world in ruins. Corvus was also known by the same people as the Great Bird of the Desert; it's hard to understand how such a small group could attain such a monstrous character.

Next to Corvus is Crater the cup. Many writers have tried to explain who this cup belonged to, and it has been assigned to virtually every major god or hero in mythology. There is yet another unanswered question: What does the cup contain? Wine, nectar, mead, fruit juices, magic potions or poison have all been poured into the cup at various times. In England it was once known as a cooking pot, and to early Arabs it was a mixing bowl; others have even called it a soup tureen.

Corvus, Crater and Hydra are found together in one Greek story. Apollo sent the crow for a cup of water, but the crow passed a fig tree on his way to the well and couldn't resist eating the fruit. Unfortunately, he waited too long for the fruit to ripen, and by the time it did so, he realized he'd been gone too long and Apollo would be angry. So the crow flew back with the empty cup and a snake in his beak and glibly explained that the snake had prevented him from reaching the well. Apollo, of course, saw through the lie (as gods invariably do), tossed all three — crow, cup and snake — into the sky, and presumably went to get his own drink. The snake

This Star Dome rendering approximates the sky as it appears at about 9 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.



Map Centered on 40° North Latitude



Map by Adolf Schaller

still stops the crow from reaching the water, but now from the cup instead of the well.

The third resident of Hydra's back is a navigational instrument: Sextans, the sextant. This constellation was invented by 17th century astronomer Hevelius, who made stellar measurements from his observatory in Danzig from 1658 until the observatory was destroyed by fire in 1679. Hevelius proceeded to place his sextant in the sky because of the good service it had given him, and situated it between Leo and Hydra because both were "fiery" signs in astrology. This noble gesture, however, has proven of little use, for Sextans is one of the faintest and least interesting sections of the entire sky.

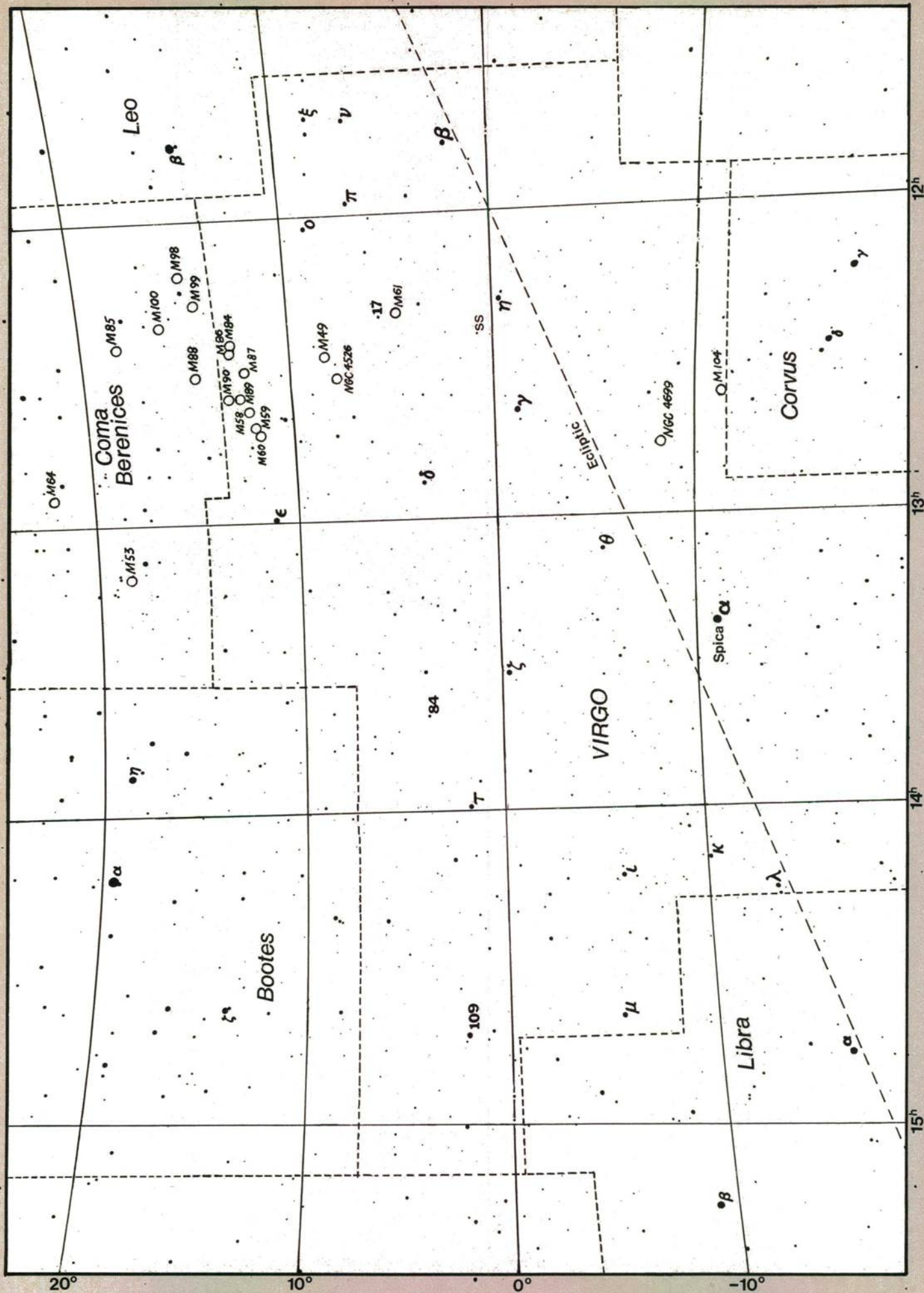
A much better invention of Hevelius' can be found farther north, beneath the handle of the Big Dipper. This is Canes Venatici, the hunting dogs, usually depicted as two greyhounds held on a leash by Bootes and pursuing the great bear around the pole. The two naked eye stars in the group represent the two dogs; the brighter of the two is named Cor Caroli, a name bestowed by Edmund Halley in honor of King Charles II of England. It forms the northernmost point of the Virgin's Diamond, and is a beautiful double star through the telescope. Canes Venatici also contains two of the brightest Messier objects: M-3, a rich globular cluster, and M-51, the well-known Whirlpool galaxy. So unlike most modern constellations, Canes Venatici is a worthwhile addition to the sky.

South of the hunting dogs is yet another small, dim constellation: Coma Berenices (Berenice's hair). This constellation is actually a widespread open cluster; if it were farther away, it would appear much smaller and more condensed. In fact, we can get a reasonably good idea from looking at Coma Berenices of how our sky would appear if the sun were located in an open cluster. Although the stars in such a group seem tightly packed from a distance, they are really not very close together; our sky would probably have only a few additional bright stars.

Coma Berenices received its current name from the famous theft of Berenice's hair. She had placed it in a temple as an offering of thanks for her husband's safe return from battle; when the hair was stolen, the court astronomer persuaded her that the hair had been transferred to the sky. The constellation was not definitely listed separately, however, until 1602, when Tycho Brahe listed it in his star catalog. Previously, it had been thought of as either the tip of Leo's tail (marked today by Denebola), a distaff or a sheaf of wheat held by Virgo, or simply as a group of "unformed" stars. The Arabians called it a pond, and the Chinese, who appear to have been greatly interested in this small group, gave names to many of its stars, mostly in commemoration of historical figures. The Egyptians knew the group simply as the Many Stars.

One reason for Coma's faintness is the fact





that it contains within its borders the north galactic pole. Thus, when we are looking at Coma, we are gazing directly outside the Milky Way galaxy. As mentioned earlier, this is the reason for the great abundance of other galaxies in this small region of the sky. Coma Berenices is the farthest of all constellations from the Milky Way, and the writer H.A. Rey has said, "Thus no hair can ever get into the milk, celestially speaking."

The great cluster of galaxies extends southward from Coma Berenices into Virgo. This second largest of all our constellations (only Hydra is bigger) is also one of the oldest, perhaps because it lies in the zodiac. Virgo has been identified since earliest times, even though it contains no immediately distinctive pattern.

The stars of Virgo have always represented a woman — one of only three in the sky. The Greeks knew her as Kore the maiden, a personification of youth and beauty. Later, when the Greeks gave the constellation more exact identifications, Virgo became Persephone, daughter of the great Earth goddess Demeter. Hades, god of the underworld, carried off Persephone to be his wife. When Demeter finally found her daughter and attempted to bring her back to Earth, she couldn't because Persephone had carelessly eaten part of a pomegranate while in the underworld. Demeter was forced to strike a bargain with Hades: Persephone would spend half the year with her mother and half with her husband.

The myth was one of several explanations the early Greeks had for the changing seasons: When Persephone was with Demeter, Earth was alive and things grew — in other words, it was spring and summer. And when Persephone returned to Hades, the growing things withered and died, Earth grew cold, and autumn and winter came.

The myth also helps explain Virgo's association with agriculture and the harvest. The maiden holds some stalks of wheat (marked by the star Spica) in her right hand, and the sun formerly passed through the constellation during the summer, when things grew. An old English custom can be traced back to this association: the last remains of the harvest were tied together into a rough imitation of a human form called the maiden, and this figure was carried through the fields after the farmers had brought the last crops home. In fact, in earlier times, the stars of Virgo had represented a girl gleaning in the fields.

Although many people saw in Virgo an innocent young girl, others pictured the constellation as a wise, mature woman — usually a goddess. To the Babylonians, she was Ishtar, queen of the stars; in Egypt the group was called Isis, chief goddess and wife of Osiris, whom the Egyptians depicted in Orion. Isis was shown holding the sheaf of wheat that she afterwards dropped to form the Milky Way. To the Romans, Virgo was Astraea, goddess of justice — the last of the immortals to leave Earth when mankind became completely wicked. The Christians of

the Middle Ages, of course, knew the constellation as the Blessed Virgin — a striking figure who combined the innocence of youth with the wisdom of maturity.

The people of ancient India thought Virgo was a woman in a ship, again holding several sprigs of wheat, while the Chinese called the group the frigid maiden. Among the very few people who did not see a woman in this group were the Arabs. To them, Virgo was a group of barking dogs in pursuit of the nearby lion, and this notion survives in the name of Beta Virginis: Zavijava, Arabic for the dogs' kennel. Later Arabian astronomers, more closely approaching Virgo's character, called the entire group a sheaf of wheat. The names of some other stars in Virgo are Vindemiatrix (Epsilon Virginis) which means grape-gatherer, another reference to the harvest, and Syrma (Iota Virginis), Greek for hem of the maiden's robe.

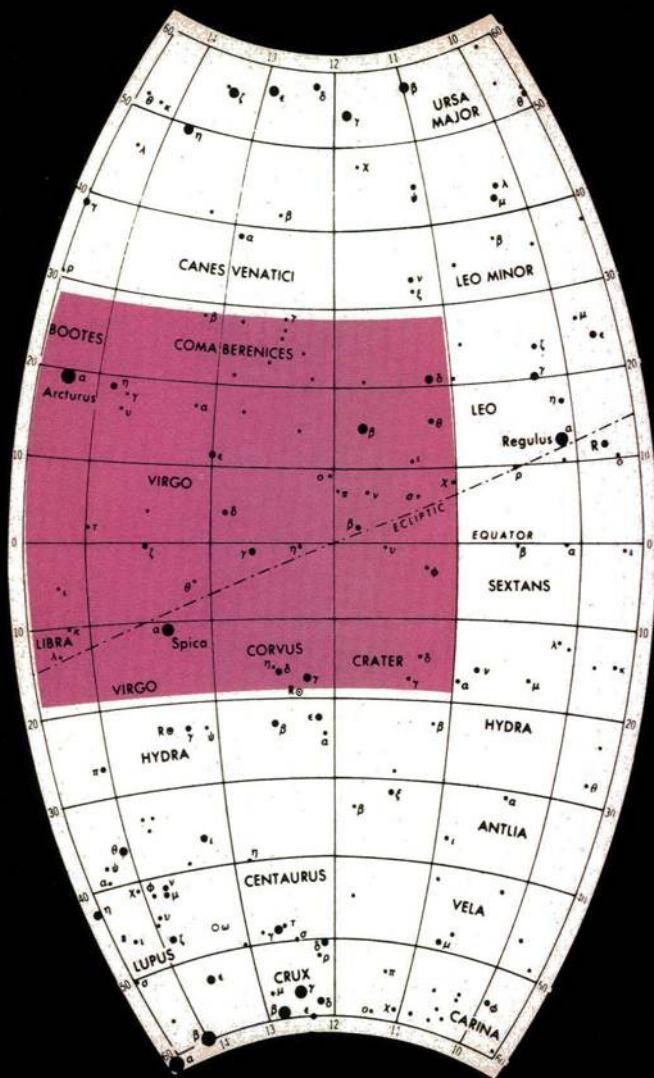
Virgo today contains the autumnal equinox — the point in the sky at which the sun is located on the first day of autumn — thus making the group even more appropriate to harvest time. If the ancients had known about the many galaxies within Virgo's borders, might they have depicted them as the seeds the maiden was scattering?

Close-Up on the Virgo Region

Virgo is well placed for observing on May evenings, lying astride the meridian facing south. Despite the constellation's large size, its stars are not very bright; only one exceeds third magnitude. Virgo's most distinctive pattern is a large "Y" formed by several of its stars. First magnitude Spica marks the base of the "Y", and the stem is formed by a line from Spica to Gamma (γ). The left arm is marked by Delta (δ) and Epsilon (ϵ), while Eta (η) and Beta (β) form the right arm. We might also think of this "Y" as a large bowl into which are pouring the galaxies of the Coma-Virgo cluster.

Mention of Virgo immediately brings to mind this vast swarm of remote galaxies, hidden beyond the virgin's visible stars. An excellent introduction to this amazing part of the night sky is that given by Webb: "A constellation especially remarkable for those possessed of adequate optical means, on account of the wonderful nebulous region, in which a far greater number of these extraordinary bodies are accumulated than in any other area of the heavens, (Sir William) Herschel having detected within its boundaries no less than 323. Few of them, however, are individually interesting; it is the mysterious thronging together of these objects, whatever may be their nature, that opens such a field for curiosity." Today, more than a century after Webb penned his remarks, we know that the "nebulous" Coma-Virgo region is actually a vast cluster of distant galaxies, numbering in the tens of thousands.

The heart of this alluring region is bounded



Map from *Guidposts to the Stars*; reprinted permission of MacMillan Publishing Co. ©1972 by Leslie C. Peltier.

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α Alpha	η Eta	ν Nu	τ Tau
β Beta	θ Theta	ξ Xi	υ Upsilon
γ Gamma	ι Iota	$\omicron$ Omicron	ϕ Phi
δ Delta	κ Kappa	π Pi	χ Chi
ϵ Epsilon	λ Lambda	ρ Rho	ψ Psi
ζ Zeta	μ Mu	σ Sigma	ω Omega

Table of Selected Objects — Virgo Region

Object	Type	Mag.	Size/Sep.	R.A. (1950)	Dec.
VIRGO					
M-61	Sp	10.1	6'x5'	12 ^h 19 ^m	+04°45'
17	★2	6.5,8.6	20"	12 ^h 20 ^m	+05°35'
SS	V:355 ^d	6.0-9.6	—	12 ^h 23 ^m	+01°03'
*M-49	E1	8.6	3'x2'	12 ^h 27 ^m	+08°16'
NGC-4526	E1	10.9	3'x1'	12 ^h 32 ^m	+07°58'
M-104	Sp	8.7	6'x2'	12 ^h 37 ^m	-11°21'
* γ (Gamma)	★2	3.6,3.6	4"	12 ^h 39 ^m	-01°11'
NGC-4699	Sp	9.3	3'x2'	12 ^h 46 ^m	-08°24'
θ (Theta)	★3	4.4,8.6,10	7".71"	13 ^h 07 ^m	-05°16'
* α (Spica)	★2(SB)	1.2	—	13 ^h 23 ^m	-10°54'
84	★2	5.7,8.6	3"	13 ^h 40 ^m	+03°47'

* Detailed in Eyepiece Impressions

★2,3,4=Double/Multiple Star SB=Spectroscopic Binary
 Sp=Spiral Galaxy Mag.=Magnitude
 E1=Elliptical Galaxy Sep.=Separation
 V=#dm=Variable Star, Period — days, hours, minutes

by Vindemiatrix (Epsilon Virginis) to the east and Denebola (Beta Leonis) on the west. Stragglers can be found as far south as Spica and north beyond Cor Caroli [Alpha (α) Canum Venaticorum]. (This region was described in "The Realm of the Galaxies", *ASTRONOMY*, June 1975.) Eyepiece Impressions this month focuses on the mid-Virgo region, centered around third magnitude Gamma. The galaxies have thinned out considerably making identification easier, and this area contains a number of other interesting objects, as our table shows.

To behold quantities of separate universes in one field of view — whether through large aperture binoculars, richest field instruments or a conventional telescope — is a breathtaking experience. Try it yourself the next dark clear night; you may come away from the celestial panorama a different person.

Eyepiece Impressions

Spica

For all their pomp and radiance, first magnitude stars are largely neglected by the telescopic observer. Yet these beacons have an appeal all their own, especially to those who appreciate heavenly hues.

The great observer William H. Pickering, in his 1917 list of the 60 finest objects in the sky, made the following remark: "...for the casual visitor who merely wishes to see something brilliant and surprising, few objects excite more admiration than a first magnitude star thrown slightly out of focus."

A perfect example of this is the star Spica (Alpha Virginis), shining due south on May evenings and enhancing an otherwise dull looking part of the heavens. Olcott tells us that "Spica is an extremely beautiful pure white star" and that it culminates (transits the meridian) at 9 p.m. on May 29 each year.

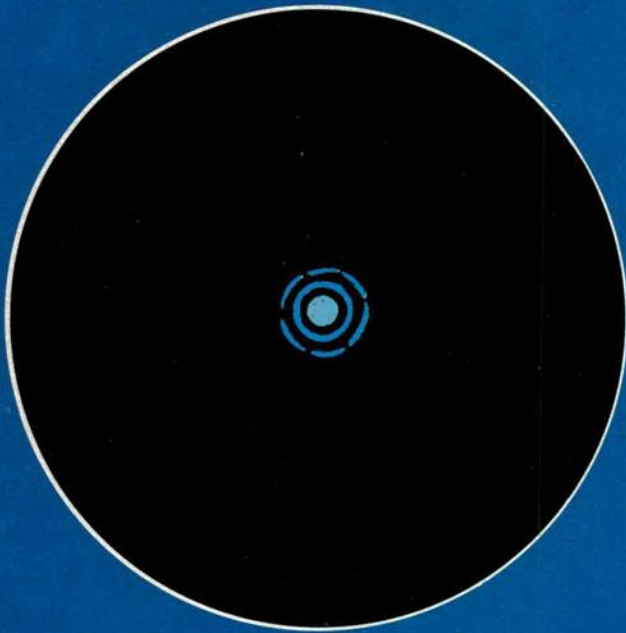
Most observers see a definite tinge of blue in this great star's light — which agrees well with its spectral class of B1. Most celestial colors are easily identified, showing that they are real and not merely subjective.

We've discussed on several occasions the virtues of observing the brighter single and double stars with small apertures at very high magnifications. At 100 power or more per inch of aperture on one to three inch telescopes, these objects display beautiful diffraction disks and ring structure caused by the wave nature of light. The larger the instrument, the smaller and less obvious these features become.

The result of observing Spica in such manner is illustrated in our drawing. Here, a three inch refractor was masked down to one inch with a cardboard aperture stop, and a power of 300 was achieved with a Barlow lens. Instead of seeking delicate hues

Spica

Gamma Virginis



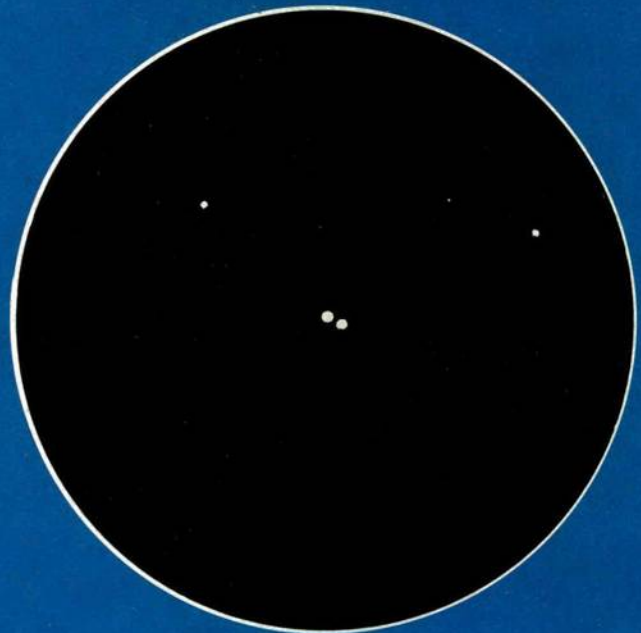
(A) 300x

Diagram A shows Spica as seen through a three inch Unitron refractor masked down to one inch at 300 power. Masking is one of the best ways to observe star colors, since the method produces bright diffraction disks that emphasize the star's hue and brightness. Gamma Virginis is shown in diagram B; a 1/3 degree field is visible through a homemade four inch reflector at 125 power. The components of this double orbit each other over a period of 172 years. This orbit is depicted in diagram C, in which the stars' present positions are given by yellow dots, and red grid tick marks indicate one second intervals. At lowest separation in 2008, the two stars will be indistinguishable in all but the largest instruments. Drawings by James Mullaney.

in a tiny pinpoint of light, we view an extended surface, making color perception definite and easy. Why not try this technique on Spica with your telescope the next clear night? If you own a large instrument, mask it down to one or two inches — on-axis for a refractor, but off-axis with a reflector or compound scope to avoid the central obstruction.

Incidentally, such unorthodox viewing is also an excellent way to check on the quality of atmospheric seeing conditions. On turbulent nights, the disk and rings go through all sorts of convulsions; in tranquil skies, they can look like a pole-on view of the planet Saturn. From experience gained on different nights and different seasons, the observer can tell much about the current state of the atmosphere at his location (such as an oncoming front) — all from the stunning diffraction image of a star as seen in a small telescope.

Aside from its lovely color, Spica is also an eclipsing spectroscopic binary with a period of four days. Both suns are similar in size, color and luminosity, and their orbital plane lies nearly in our line of sight. As a result, grazing eclipses of one star by the other occur, causing Spica to vary slightly (about 0.1 magnitude) on a regular schedule.



(B) 125x N

At its distance of 220 light-years, this rapidly revolving pair is too close to resolve visually in any existing telescope. If, however, we could view this system from a planet circling the pair, we would behold a blazing duo of blue-white suns passing across the alien sky.

Gamma (γ) Virginis

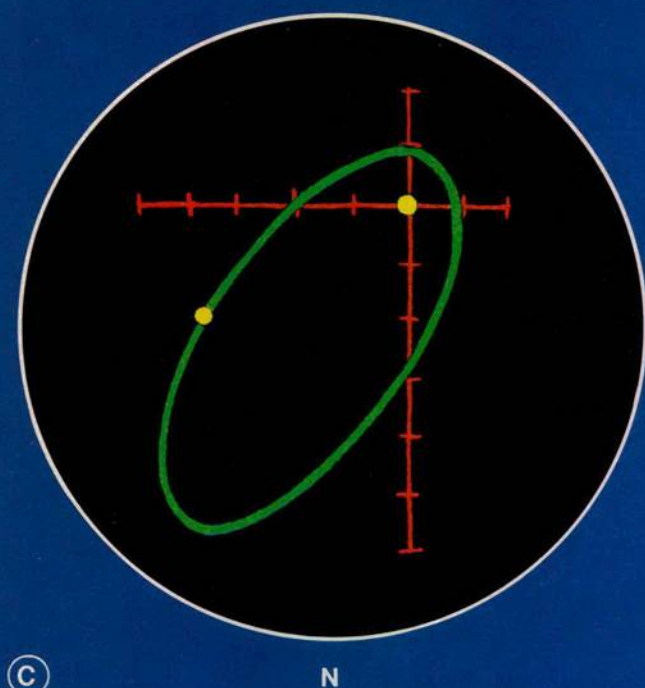
A surprising number of the "Gamma" stars among the constellations are striking doubles, including those in Leo, Delphinus, Andromeda and Aries. Certainly one of the finest is third magnitude Gamma Virginis, situated northwest of Spica.

Known as Porrima, this splendid pair consists of perfectly matched 3.6 magnitude stars, separated at present by four seconds of arc. The color of each sun is white with a tinge of yellow, which matches their assigned spectral class of F0.

Gamma is a beautiful sight in almost any size telescope. A 2.4 inch refractor neatly resolves the duo at 70 power in good seeing. In six inch and larger instruments at 100 power or higher, the double is sure to please visitors at the telescope. Although lacking the vivid color contrast of many doubles, this pair's intensely matched images have an appeal all their own — and unlike other deep sky objects, bright doubles like Gamma can be easily seen even in bright moonlight or on hazy nights.

This double was one of the first ever discovered (in 1718), and is one of the best studied binary systems in the sky. It is notable for its conspicuous orbital motion, resulting from its relatively short period of 172 years and its proximity to us — Gamma is only 32 light-years away. If Gamma were 10 times its present distance, it would be unresolvable even

Apparent Orbit of Gamma Virginis



in large amateur instruments for most of its orbit.

At its widest separation of six seconds of arc, which occurred in 1919, the pair is easy even in very small telescopes. However, when at their closest (such as in 1836), the two stars appear single in all but the largest instruments. Gamma is presently closing again, and its separation will reach a minimum of 0.4 seconds in 2008 A.D.

At widest separation, or *apastron*, the change in relative position angle of the components is quite slow (about 0.3 degrees per year). But at closest approach, or *periastron*, this rate reaches more than 70 degrees a year — easily noticeable even to the casual observer. Position angle is defined as the location of the companion with respect to the primary. Due north is considered as 0 degrees, east 90, south 180 and west 270 degrees. The companion's present position angle — near 300 degrees — is decreasing, and it will lie due west of the primary about the year 2000 A.D. The actual physical separations of the two stars are approximately six billion miles at *apastron* and 400 million miles at *periastron*.

A given telescope-eyepiece combination that barely splits Gamma today will, during the next few years, show the components touching and then merging into an unresolved blob — vivid proof of stellar motion in the depths of space!

Writing in 1859, Webb said, "This wonderful pair has been widening ever since they closed up out of all telescopic reach in 1836. He added the following interesting comment: "Silver white, pale yellow; white the brighter but colors not always equally intense. Struve thought them alternately variable in brightness, with possible period of at least several years." Are such suspected changes in color and

luminosity for closely matched pairs like Gamma illusory or real? Here's an ideal project for the observer who loves double stars and has lots of patience.

M-49

South of the main horde of galaxies populating the Coma-Virgo region is an easily found galaxy shining in isolated splendor. This is the giant elliptical system known as M-49. You can readily pick it up by sweeping the area just northwest of the sixth magnitude star at the center of a triangle formed by Delta, Omicron (o) and Epsilon Virginis. Use a low power, wide field eyepiece on a dark night.

Although it lies amid a small group of other galaxies, M-49, at magnitude 8.6, stands out from its neighbors which glow at or below 11th magnitude. About three by two minutes of arc in extent, this distant star city can be seen in a three inch refractor at 45 power, even without the use of averted vision. Large apertures, however, definitely have the advantage for viewing galaxies; in this case, the bigger the telescope, the better the view.

Webb described M-49 with his 3.7 inch refractor as a "faint haze in beautiful position between two six magnitude stars". Barns also mentions these two stars and calls this object a "notable nebula" in his 10 inch reflector.

Practice in locating M-49 and its fainter neighbors will make your roamings through the nearby Realm of the Galaxies more enjoyable, and you'll more easily identify individual objects. It's easy to become lost in this vast extragalactic hunting ground!

Most of us who spend time at the telescope on clear nights realize that we must observe with the mind as well as the eyes to fully appreciate the varied scenes that pass through the eyepiece in quiet review. This is especially true in the case of galaxy observation, where a faint glow of light near the limit of visibility represents an entire universe of stars.

Perhaps even more important is our responsibility to adequately prepare friends we invite to share our views of the night sky. Even a bright galaxy like M-49 can be a disappointing experience to a first-timer at the telescope unless he realizes the significance of what he is seeing. The light from a galaxy is composed of the actual photons that departed from that object and traveled through space for millions of years to reach his eye at the telescope.

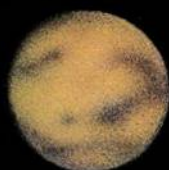
Robert Burnham, in his *Celestial Handbook*, made the point beautifully: "...the amateur astronomer has access at all times to the original objects of his study; the masterworks of the heavens belong to him as much as to the great observatories of the world. And there is no privilege like that of being allowed to stand in the presence of the original."

Planet Finder



© Ceres

May	1	15
R.A.	5h42m	6h09m
Dec.	+26°41'	+27°02'
Mag.	+8.6	+8.7



Ⓐ Mercury

May	1
R.A.	3h55m
Dec.	+23°03'
Mag.	+0.9

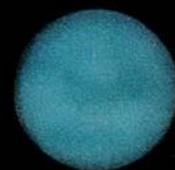
Ⓑ Mercury

May	15
R.A.	3h59m
Dec.	+20°41'
Mag.	+3.0



Ⓜ Mars

May	1	15
R.A.	7h36m	8h09m
Dec.	+23°24'	+21°48'
Mag.	+1.5	+1.6



Ⓝ Neptune

May	15
R.A.	16h47m
Dec.	-20°48'
Mag.	+7.7



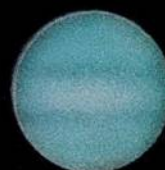
SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.



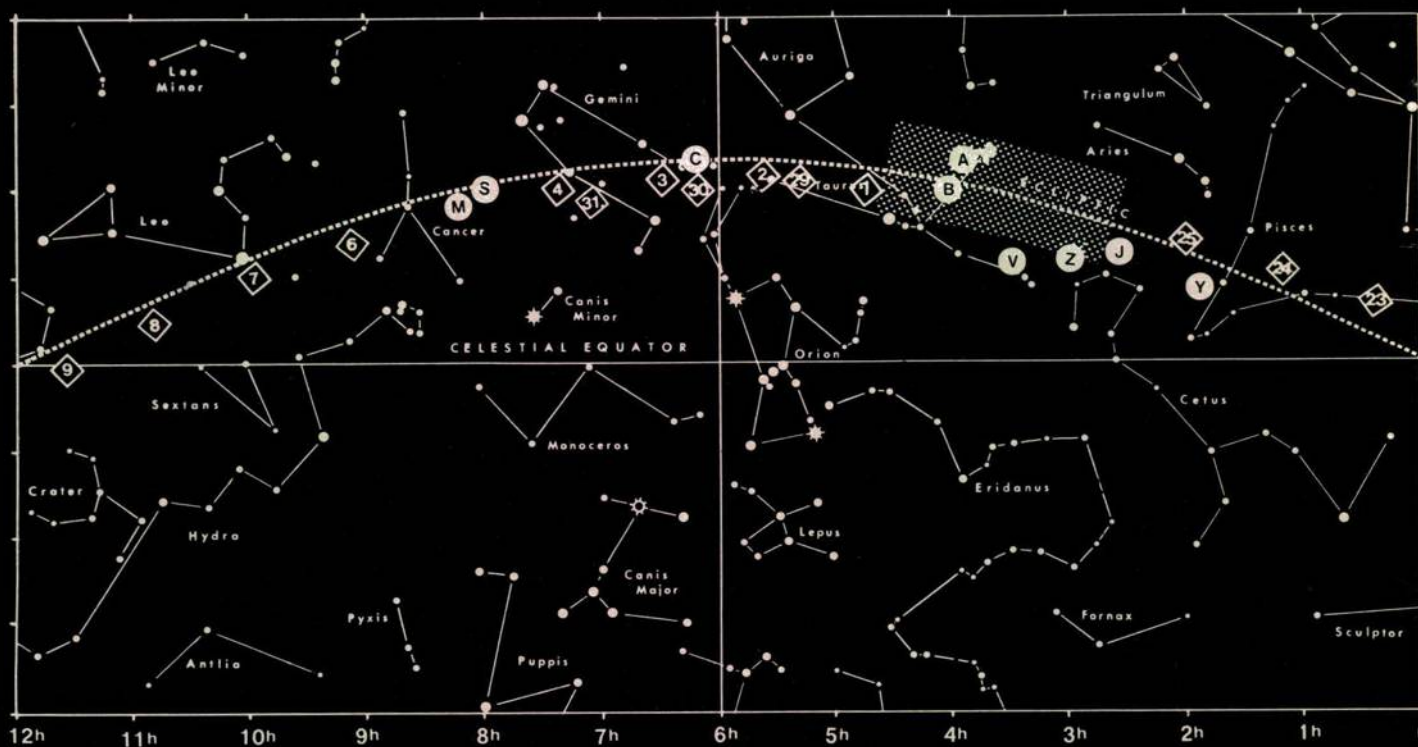
Ⓢ Saturn

May	1	15
R.A.	7h57m	8h01m
Dec.	+21°08'	+20°57'
Mag.	+0.4	+0.5



Ⓤ Uranus

May	15
R.A.	14h08m
Dec.	-12°27'
Mag.	+5.7



The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

May 1976



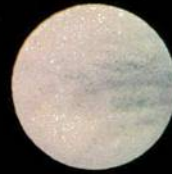
(V) Vesta

May	1	15
R.A.	3h06m	3h31m
Dec.	+13°14'	+15°00'
Mag.	+9.0	+9.0



(J) Jupiter

May	1	15
R.A.	2h26m	2h39m
Dec.	+13°28'	+14°31'
Mag.	-1.6	-1.6



(Y) Venus

May	1	
R.A.	1h50m	
Dec.	+9°54'	
Mag.	-3.3	

(Z) Venus

May	15	
R.A.	2h56m	
Dec.	+15°46'	
Mag.	-3.4	



(P) Pluto

May	15
R.A.	13h00m
Dec.	+12°24'
Mag.	+14



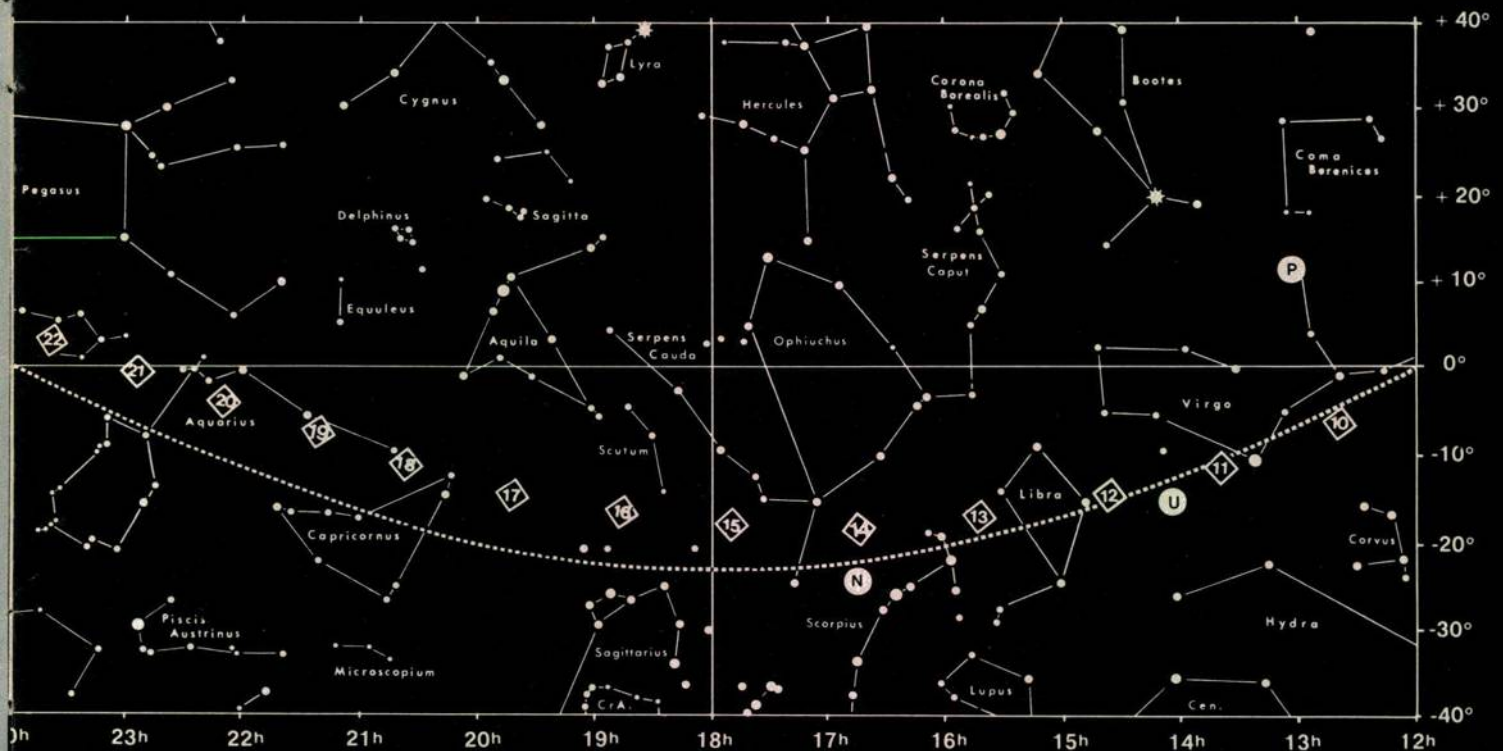
First Quarter
May 7



Full Moon
May 13



Last Quarter
May 21



measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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